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ABSTRACT

This manual on belts and chain drives is one of a series of power mechanics texts and visual aids on theory, of operation, diagnosis, and repair of automotive and off-the-road agricultural and construction equipment. Materials provide basic information and illustrations for use by vocational students and teachers as well as shop servicemen and laymen. Focusing on belts, the first of two parts addresses topics such as advantages and disadvantages of belts, types of belts, comparison of belts, operation of V-belt drives, reading V-belt sizes, V-belt pulleys and sheaves, relative output speed of belt drives, variable-speed belt drives, belt tension mechanisms, mechanical interference, sheave groove wear, replacing sheaves, installing V-belts, maintenance of flat belts, wear on flat belts, and trouble shooting belt drives. Part 2 focuses on chains and addresses topics such as principles of chain drives, advantages and disadvantages of chains, uses of chains, types of chains, drive arrangements, matching chains and sprockets, relative speed of sprockets, aligning shafts and sprockets, chain slack, lubricating chains, chain wear, and trouble shooting chain drives. Each part concludes with test questions. Answers to the test questions are appended. (A supplementary 35mm color slide set is also available--see availability note.) (LRA)

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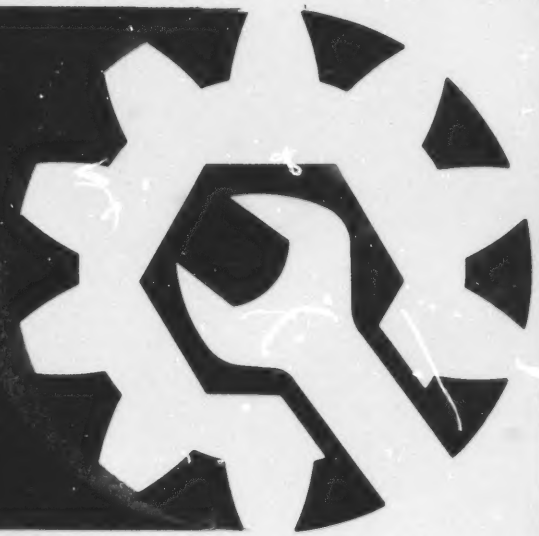
Belts and Chains

JOHN DEERE

FOS

FUNDAMENTALS OF SERVICE



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TO THE READER

PURPOSE OF THIS MANUAL

The main purpose of this manual is to train the reader so that he can understand belt and chain drives and service them with speed and skill. Starting with "how it works," we build up to "why it fails" and "what to do about it." This manual is also an excellent reference for the trained serviceman who wants to refresh his memory on belt and chain drives. It is written in a simple form using many illustrations so that it can be easily understood.

WHAT IS "FUNDAMENTALS OF SERVICE"?

This manual is part of a series of texts and visuals called "Fundamentals of Service", or "FOS". These materials are basic information in power mechanics for use by teachers as well as shop servicemen and the layman. All types of modern equipment are covered — both automotive and off-the-road. Emphasis is on theory of operation, diagnosis, and repair.

OTHER MANUALS IN THIS SERIES

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BELTS / PART 1

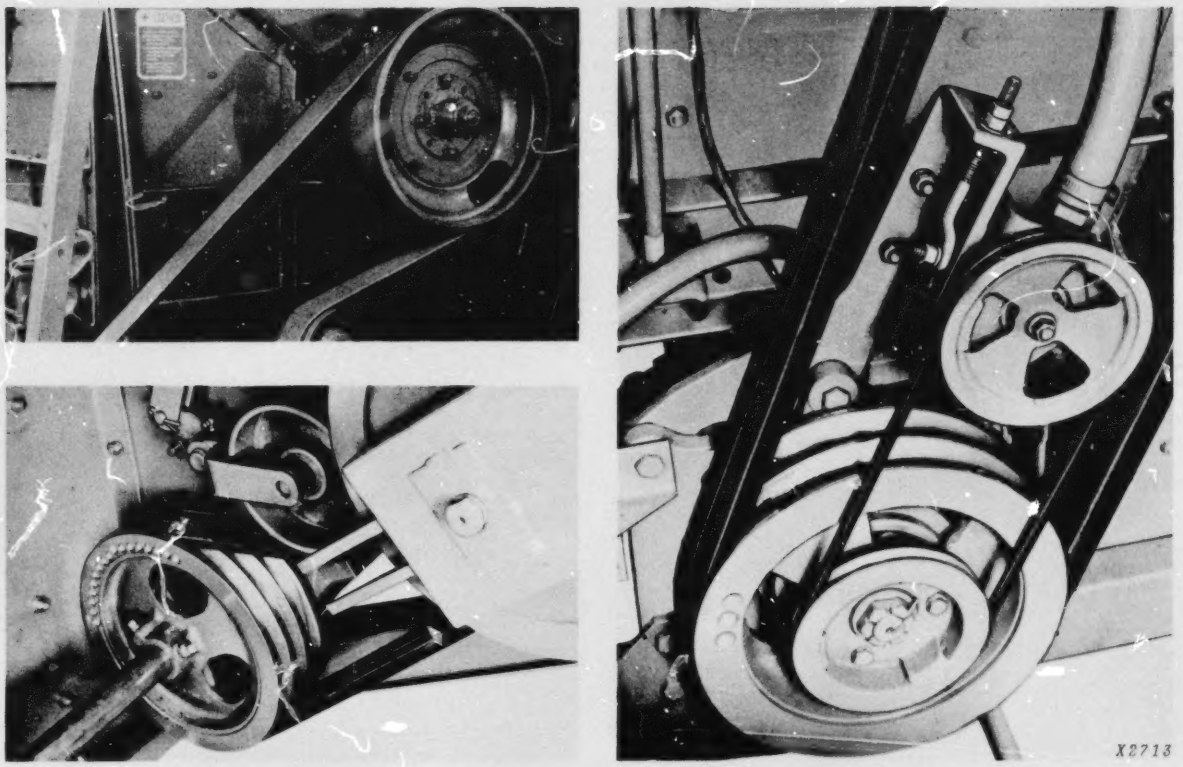

Fig. 1 — Belt Drives

INTRODUCTION

Belt drives are **frictional** drives. They transmit power by contact between the belt and the driving and driven pulley.

The ability of belts to transmit power depends on:

1. *Tension holding the belt to the pulleys.*

2. *Friction between belt and pulleys.*

3. *Arc of contact (or "wrap") between belt and pulleys.*

4. *Speed of belt.*

Belts are normally used to transmit power between two parallel shafts but they are flexible and can also be used in a variety of other ways.

ADVANTAGES OF BELTS (Compared With Chains)

1. Belts require no lubrication.

2. Belt drives generally operate with less noise.

3. Flat belt drives can be used where *extremely* long center distances make chain drives impractical.

4. Flat belts are advantageous for extremely high speeds.

5. Single belt drives will accept more misalignment than chain drives.

6. Many belt drives are less expensive for low horsepower and low ratio applications.

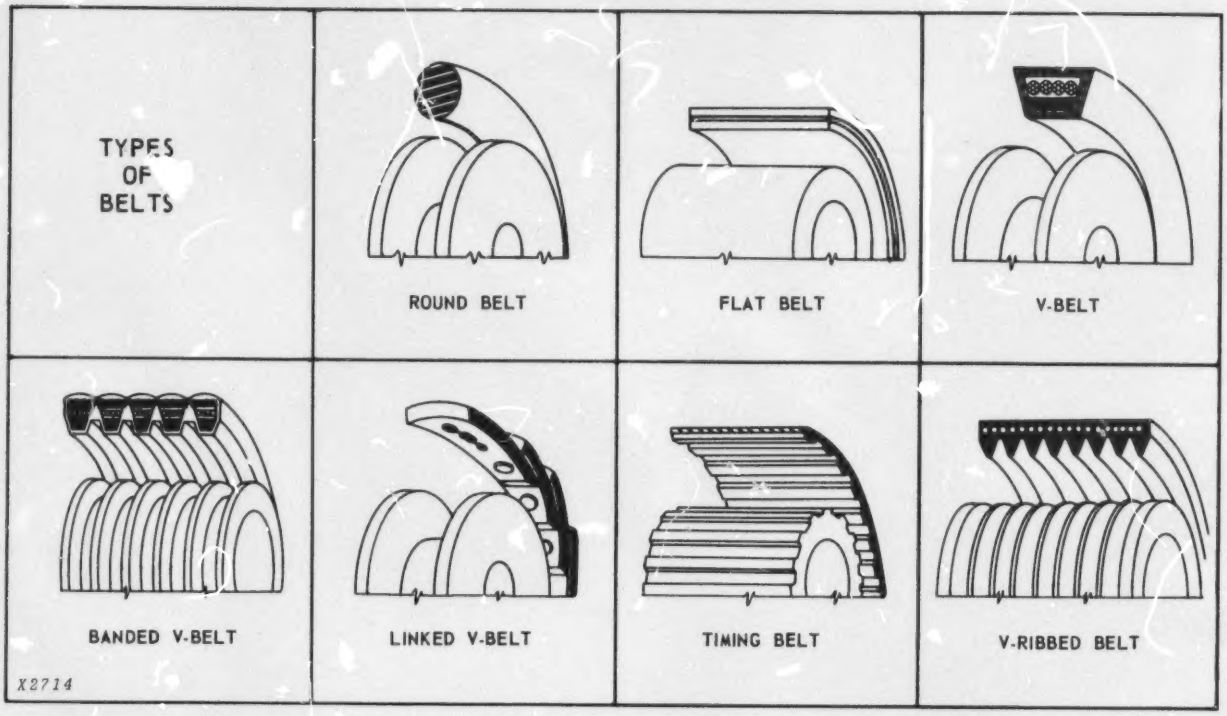

Fig. 2 — Types Of Belts

DISADVANTAGES OF BELT DRIVES

1. Belts are more easily damaged by oil, grease, and heat.

2. Belts cannot be used where exact timing or speed is required (unless a special timing belt is used).

TYPES OF BELTS

Seven major types of belts are used in modern belt drives (Fig. 2):

- **Round belts**
- **Flat belts**
- **V-belts**
- **Banded V-belts**
- **Linked V-belts**
- **Timing belts**
- **V-ribbed belts**

Let's look at each belt in detail.

ROUND BELTS

Round belts are usually made of solid rubber or rubber with cords. These belts are normally made for relatively light loads, such as for sewing machines and movie projectors. However, larger round belts are sometimes used on farm equipment.

FLAT BELTS

Use of flat belts has decreased because most machines today have built-in drives or use V-belts. Their most common use is in drives where high power is needed for a separate machine. *Examples:* old-time threshers, sawmills.

Flat belts are also used as conveyor belts where the belt itself performs the work, such as on conveyors and draper belts.

Disadvantages of flat belts are that they need larger pulleys and so take more space; they are also less flexible than some other belts.

Advantages are simplicity, strength, low first cost, and resistance to extreme dust.

On continuous drives, automatic *tension* on the flat belt is needed. Idler pulleys are usually avoided because they put a reverse bend on the belt. So the drive pulley is often mounted on a motor with a slide rail or pivoted base.

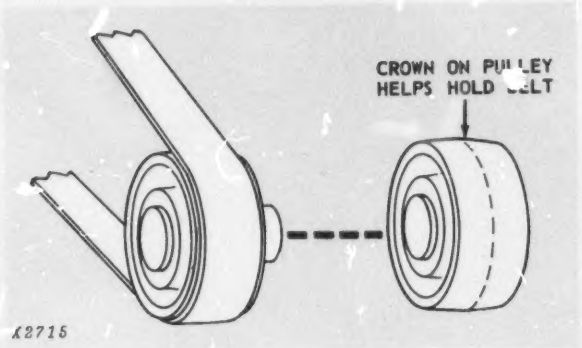

Fig. 3 — Crown Helps Keep Flat Belt On Pulley

Pulleys for flat belts are most often cast iron, steel or wood, and usually are crowned at the center to help keep the belt on the pulley (Fig. 3).

Flat belts are usually made of leather, rubberized fabric and cord. Both rubber and leather in a variety of designs are available for operation in adverse conditions — oil, heat, static electricity and moisture. All these conditions reduce friction, cause the belt to slip and wear excessively.

1. **Leather belts** are normally made of tanned steer hides. The belts are formed into single, double, or multiple layers and may be combined with other materials such as cords, fabric, and polymers. Leather belts are also made in links for heavy slow-speed drives with possible high slippage.

2. **Flat rubber belts** are made from fabric or cord impregnated with natural or synthetic rubber compounds. These give varying degrees of strength, stretch, pulley grip, and protection against abrasion, oil and moisture.

3. **Flat fabric belts** are made from 3 to 12 plies, depending on width. The fabric can be cotton or synthetic fiber with or without rubber impregnation. Load and speed characteristics are moderate. Such belts are usually supplied endless; straight lengths can also be spliced in the field.

4. **Flat cord belts** are made from cotton or synthetic material, and are usually supplied endless. They are generally heavy-duty belts used for high-speed, small-pulley and shock-load applications. Steel-cable belts can serve similarly; they have higher capacity and lower stretch than cord constructions.

Perfect alignment of pulleys and belt is a must for good operation of flat belts.

Tension should be no more than needed to transmit the load with the least slippage. However, tension is normally greater than for V-belts.

V-BELTS

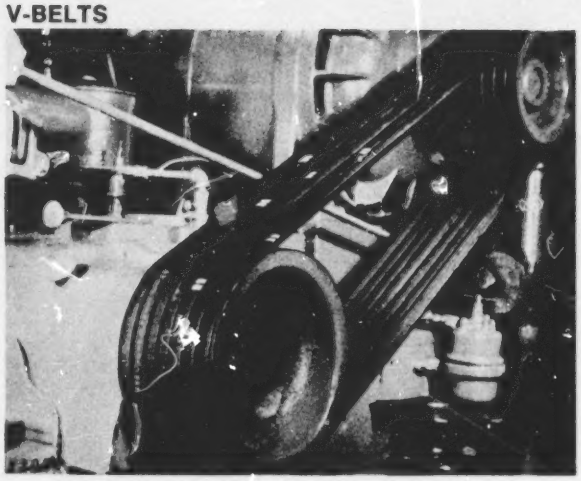

Fig. 4 — V-Belt Drive Using Multiple Belts

V-belts are the most common way of driving loads between short-range pulleys or sheaves. The simple *wedging action* of the belt against the sides of the sheave groove is the outstanding feature of V-belts. A greater pull or load merely results in a tighter belt grip.

Advantages of V-belts are:

- *Wedging action permits lower arc of contact on small pulley and a large speed ratio.*
- *Shorter center distances can be used for a compact drive and use of streamlined belt guards.*
- *Absorb shocks to cushion motors and bearings against load fluctuations.*
- *Vibration and noise levels are low.*
- *Maintenance and replacements are quick and easy.*
- *Power transmission efficiency is as high as 95%.*

V-belts are limited, with exceptions, to a practical speed range of 1000 to 10,000 feet per minute (300 to 3000 meters per minute). Some manufacturers recommend 4500 fpm (1375 meters per minute) as the most efficient speed.

Special drives can be designed for 10,000 fpm (3000 meters per minute) or more, but sheaves here require dynamic balancing to reduce the effect of centrifugal force.

Another limitation is the need to match belts in multiple drives to assure equal distribution of load among all the belts. (Banded V-belts are one solution to this problem.)

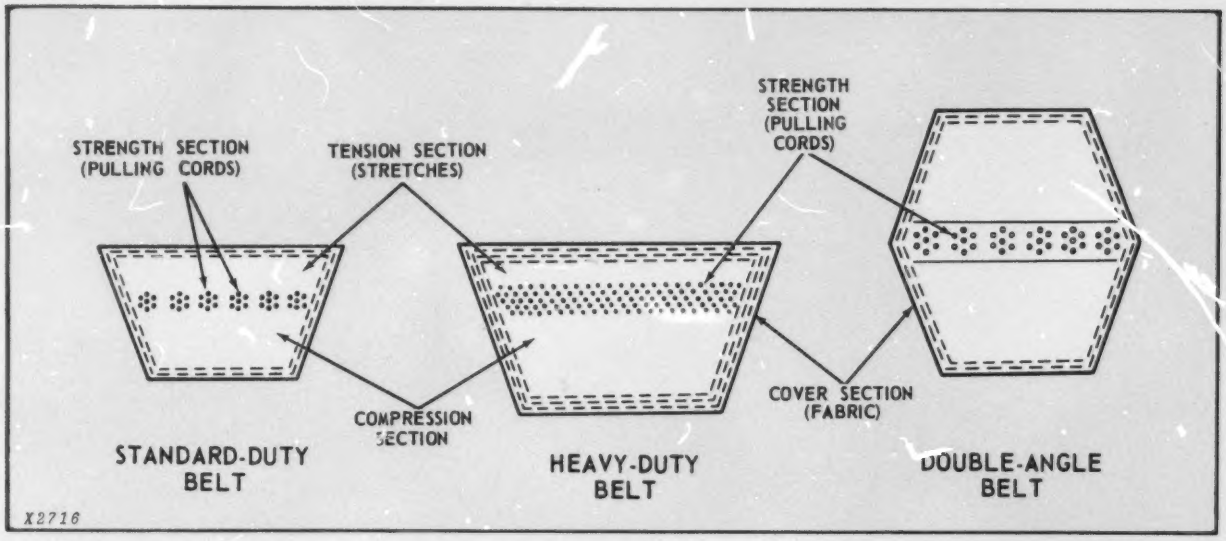

Fig. 5 — Construction Of Common V-Belts

NOTE: "Pulleys" used with V-belt drives are often called "sheaves". Either term is correct.

V-Belt Construction

V-belts are made in several types (Fig. 5), but each one is made up of four sections.

The top section of the belt is known as the *tension section* (Fig. 5). It is rubber and *stretches* as the belt forms around the sheave.

The bottom section is called the *compression section* because it *compresses* when wedged into and shaped around the sheave.

The center section of the belt is known as the *strength section*. It neither compresses nor stretches, but the cords located in this area give the belt its *tensile strength*. Without these cords, a V-belt would be pulled in two.

The complete belt is covered by a *cover section* of tough fabric and rubber which protects the inner parts. (Some belts — called "raw edge" have no fabric cover on the sides.)

Notice in Fig. 5 that the *heavy-duty* belt uses a different material for the cords and may use a heavier fabric cover than the *standard-duty* type.

Double-angle V-belts are used for drives where both the top and the bottom of the belt must contact sheaves as in a serpentine drive. In these belts, the strength cords are in the center of the belt and either side and absorb compression and tension forces.

Some V-belts also have corrugated undersides for greater flexibility.

Most V-belts are endless, but open-end types are produced for use where a closed belt cannot be installed. The ends have metal fasteners joined by a pin, or a link and two pins.

For more on V-belt design, see page 6, "Operation Of V-Belt Drives."

BANDED V-BELTS

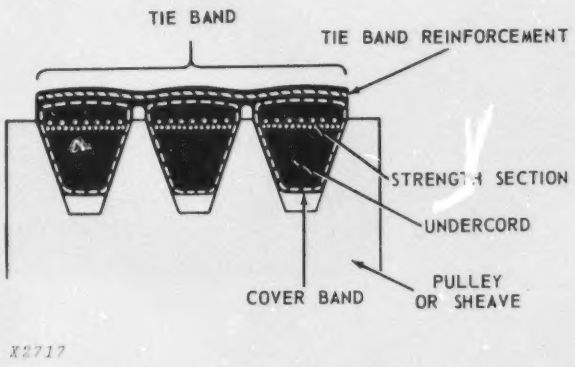

Fig. 6 — Construction Of Banded V-Belt

Banded V-belts are multiple belts which have been permanently vulcanized to a tie band (Fig. 6). This reduces problems on drives where belts may whip, turn over, or jump off.

The same belt tension can be used as for multiple strands of V-belts.

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LINKED V-BELTS

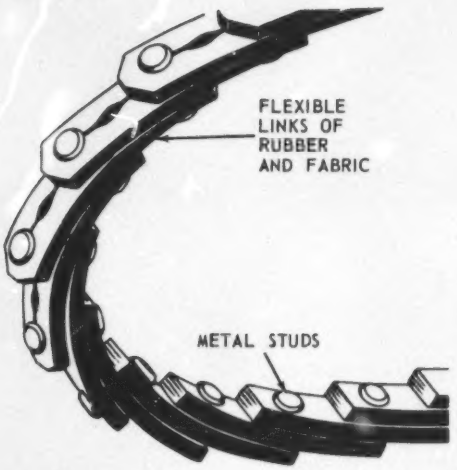

Fig. 7 — Linked V-Belt

Link-type V-belts simplify assembly of multiple-belt drives where it would be difficult to match length of each belt, especially on large fixed-center drives. Links can be added or removed to match the drive.

This belt has most of the advantages of the V-belt, except that it is not recommended for speeds over 5000 feet per minute (1525 meters per minute) and can only transmit light loads.

A minor disadvantage: The individual links add up to a larger area exposed to weathering and moisture. This requires extra rubber-sealing protection.

The flexible links are laminated of tough fabric and rubber and are held by metal studs secured with washers. The links are shaped so that the sides of the complete belt fit a standard sheave groove.

TIMING BELTS

Timing belts (Fig. 8) combine chain and sprocket action with the simplicity of flat belts.

They are essentially flat belts with teeth, equally spaced on the surface, in contact with a toothed pulley.

Continuous, helically wound cables are embedded in the belt as the load-carrying element. Neoprene backing and teeth are bonded to the steel cables to provide shear resistance and protection from dust, oil, and moisture. Many timing belts contain fiber glass cords.

Like gear and chain drives, these drives require precise alignment of pulleys and must be made endless.

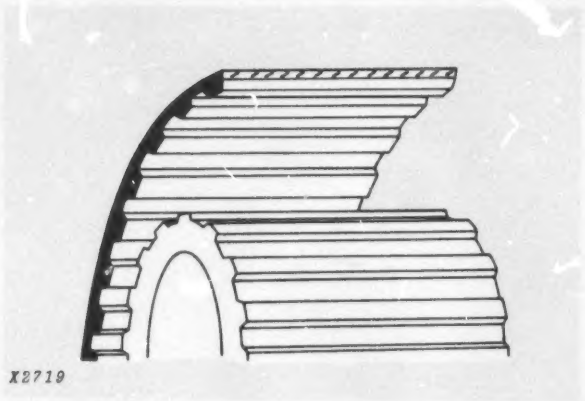

Fig. 8 — Timing Belt

Advantages of timing belts:

- *No slippage or speed variation.*
- *The teeth are rigid yet flexible lengthwise, reducing stretch.*
- *Little maintenance is required.*
- *Wide range of load and speed, from fractional horsepower to 80 hp.*
- *Lowest bearing loads of any belt drive, because of positive tooth action.*
- *Compact because of small pulleys, short centers, narrow belts and high capacity.*
- *Good mechanical efficiency because of no friction, reduced initial tension, and thin construction.*
- *High horsepower-to-weight ratio.*

V-RIBBED BELTS

V-ribbed belts (Fig. 9) are an outgrowth of the ordinary V-belt. It combines the strength and simplicity of the flat belt with the positive tracking of V-belts. V-ribbed belts eliminate the matching problem in multi-V-belts, although sheaves must be grooved to mate precisely with the belt. The pulleys must also be precisely aligned.

V-ribbed belts are made of molded rubber. A ply of strength cords run across the "flat" section of the belt. Most of these are oil- and heat-resistant and will conduct static electricity.

Unlike V-belts, which depend on wedging action to transmit power, V-ribbed belts depend entirely on friction between sheave and belt. Tension is somewhat greater than for conventional V-belts.

COMPARISON OF FIVE BELT TYPES

	FLAT BELT	ORDINARY V-BELT	LINKED V-BELT	TIMING BELT	V-RIBBED BELT
TENSION-BEARING LOADS	Highest	Low	Low	Lowest	High
BEST OPERATING RANGE, fpm (meters per minute)	1,000 to 10,000 (300 to 3000)	1,000 to 10,000 (300 to 3000)	1,000 to 5,000 (300 to 1525)	1,000 to 10,000 (300 to 3000)	1,000 to 6,000 (300 to 1830)
PERFORMANCE ABOVE 5000 fpm (1525 meters per minute)	Good	Fair	Not recommended	Good	Fair
PERFORMANCE BELOW 1000 fpm (300 meters per minute)	Fair	Fair	Fair	Good	Fair
RESISTANCE TO SHOCK LOADS	Good	Good	Good	Fair	Good
MECHANICAL EFFICIENCY	Good	Good	Good	Best	Good
EASE OF BELT SPLICE	Good in some types	Good in some types	Excellent	(Endless belt)	(Endless belt)
MISALIGNMENT TOLERANCE	None	Compensates best	Compensates best	None	None
MINIMUM DOWNTIME	Good	Best	Best	Good	Good
NOISINESS	Most	Very Little	Little	Little	Little
SYNCHRONIZES OPERATIONS	No	No	No	Yes	No
CREEP	Some	Negligible	Some	None	Some
INITIAL COST	Low	Low	Moderate	Moderate	Moderate
RESISTANCE TO WEATHER	Good	Good	Fair	Good	Good
MAINTENANCE NEEDED	Some	Negligible	Some	Negligible	Some

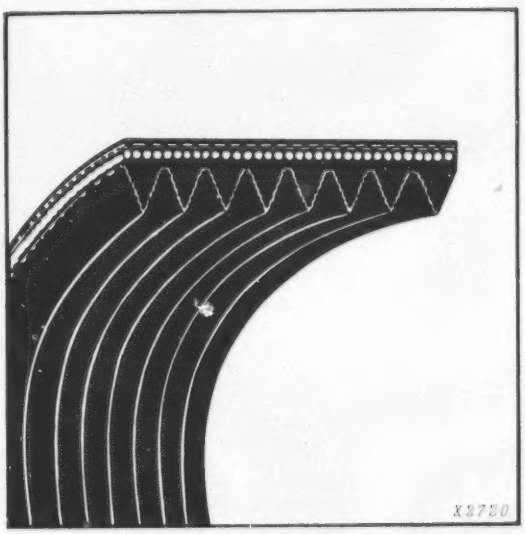

Fig. 9 — V-Ribbed Belt

Recommended speeds for V-ribbed belts are in the range of 200 to 10,000 fpm (60 to 3000 meters per minute) for up to 10-hp (7.5 kW) ratings. Most of the effective applications are on small sheaves and short centers.

SUMMARY: TYPES OF BELTS

The chart above compares the qualities of five major belts.

OPERATION OF V-BELT DRIVES

Because they are so common, let's look at the operation of V-belt drives in more detail.

HOW A V-BELT GRIPS

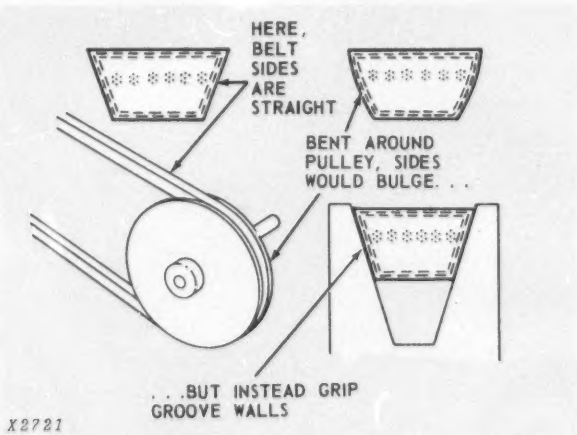

Fig. 10 — How A V-Belt Grips

Due to the wedging action of their angled sides, V-belts pull well. The section going around a pulley tends to bulge as it bends, hugging the flanges tightly.

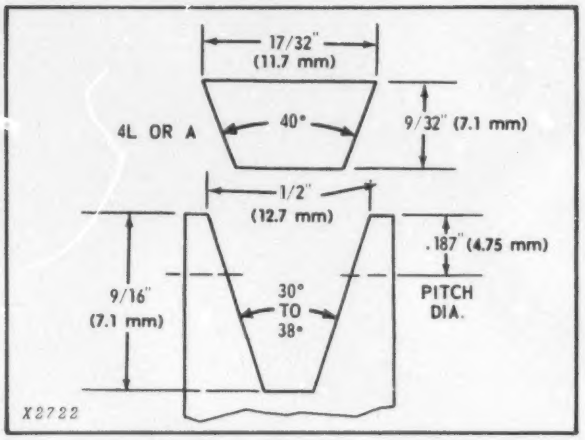

Fig. 11 — Belt And Sheave Groove Dimensions

The angle between standard belt sides is 40 degrees; the angle between the two sides of the pulley (or sheave) groove is somewhat less to insure full wedging contact (Fig. 11).

The groove is much deeper than the belt, for a standard V-belt must never ride the bottom of the groove. If it does, it loses almost all traction, no matter how taut.

READING V-BELT SIZES

V-belts are made in the various types and sizes shown in Fig. 12 on the next page. Industry codes are shown below each belt cross-section and widths and depths for each size are included.

Common V-belts range from ¼ (6.3 mm) to 1½ (38.1 mm) inch widths. But you will rarely find these fractions on a belt. Markings usually show the width, duty type, and length in a simple code, but the code varies among manufacturers.

In a typical marking such as 3L405, for example, the 3 stands for ⅜" nominal width, the L for light duty, and the next three digits for belt length in inches — the last one in tenths of an inch (usually zero, meaning no fraction; or 5, for ½"). The 3L405 belt is therefore 40½" long.

Each type of belt comes in a wide range of lengths.

When replacing a belt, try to use the figures on the old belt. If they're not legible, don't measure the belt — it will have stretched. Pull a steel tape around the outside of the two pulleys, first slacking off the tensioning adjustment to one quarter of its take-up distance. You'll need the remaining three-quarters to take up the initial stretch of a new belt, and a little more from time to time, for V-belts get longer — never shorter — in use.

Never buy a belt so tight that it has to be pried over the sheaves. This breaks the pulling cords inside. And always buy the belt to suit the job.

PULLEYS OR SHEAVES

For most V-belt drives, sheaves are available in formed steel or cast iron. Typical sheaves are shown in Fig. 13 on page 9.

Standard sheaves are made with either regular or deep grooves. A deep-groove sheave is generally used whenever the V-belt enters the sheave at an angle — as, for example, in a quarter-turn drive — on vertical shaft drives, or wherever belt stability is a problem.

Applications

Formed-steel sheaves are used primarily in light-duty applications (2L, 3L, 4L, and 5L belts), and in automotive or agricultural service.

Cast-iron sheaves are used in all types of V-belt drives. They are almost always used in applications with fluctuating loads, where flywheel effect is important.

Special Sheaves

Sheaves can be made of a number of materials other than formed steel and cast iron. V-belt sheaves are sometimes steel or aluminum alloy. For some very light-duty applications, plastic or die-cast sheaves are used.

Where operating conditions are severe, special materials such as stainless steel are sometimes used. Frequently, a less expensive solution is to use a cast-iron sheave coated with a special finish, such as a black-oxide. These sheaves are especially resistant to abrasion.

Hubs

Formed-steel sheaves almost always have an integral hub. Multiple-V and ribbed-V sheaves are made with either integral or interchangeable bushings to fit various shaft sizes.

Most sheaves are keyed to their shafts and then either set-screwed or secured with a hex nut and lock washer.

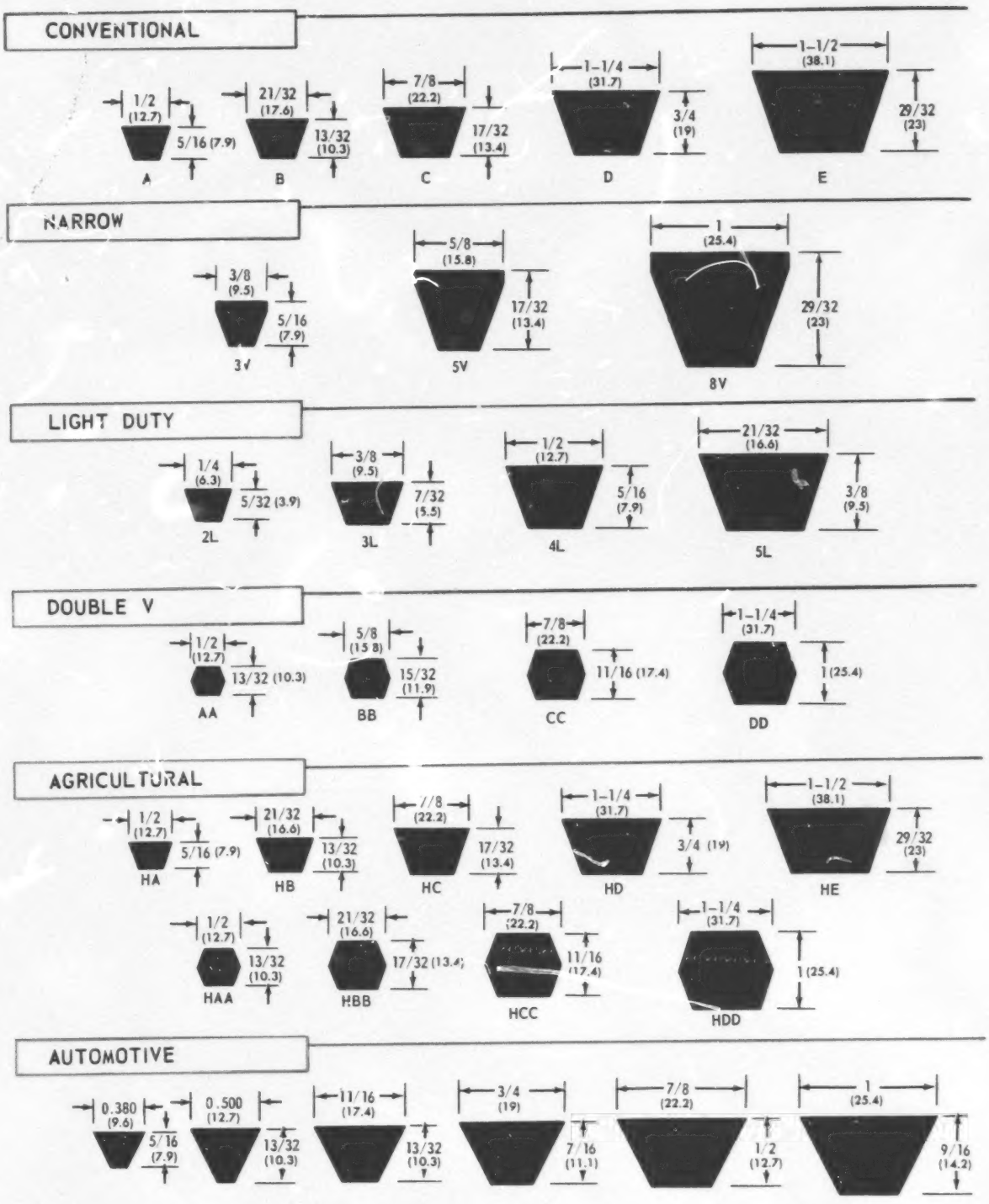

Fig. 12 — Types And Sizes Of V-Belts (Numbers In Parentheses Indicate Size In Millimeters)

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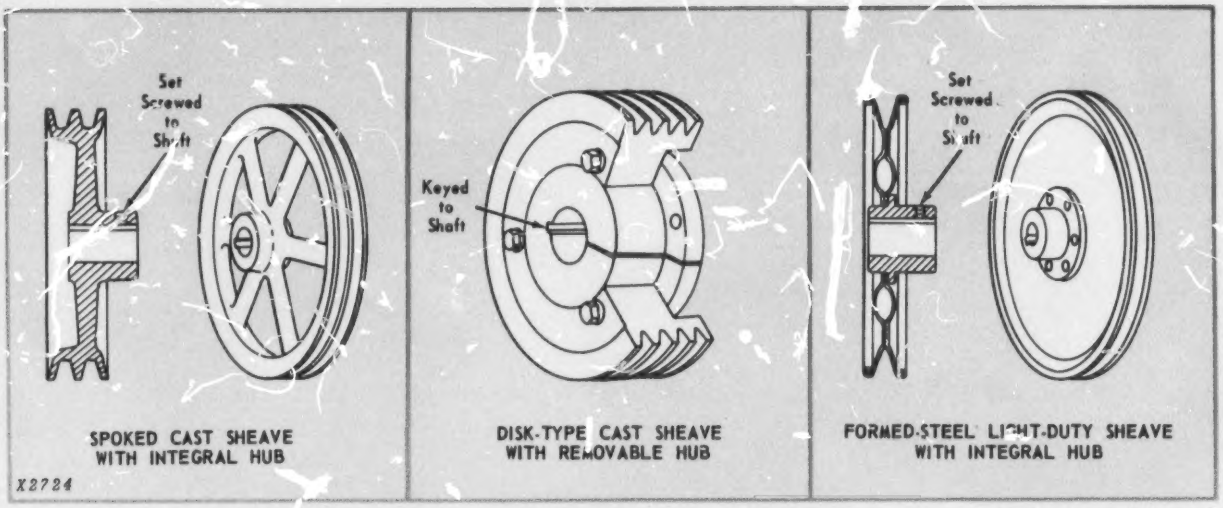
Set Screwed to Shaft
Keyed to Shaft
Set Screwed to Shaft
SPOKED CAST SHEAVE WITH INTEGRAL HUB
DISK-TYPE CAST SHEAVE WITH REMOVABLE HUB
FORMED-STEEL LIGHT-DUTY SHEAVE WITH INTEGRAL HUB
X2724

Fig. 13 — Types Of Sheaves For V-Belt Drives

Numbers of Grooves

Multiple-V sheaves are generally stocked in the following numbers of grooves: A and B sections, 1 to 10 grooves; C, 1 to 12; D, 3 to 20.

Balancing Of Sheaves

Most standard sheaves are statically balanced and are satisfactory for rim speeds up to 6000 fpm (1830 meters per minute) (6500 fpm [1980 meters per minute] for narrow-belt sheaves). In some cases a special design or special materials may also be needed.

How Pulley Sizes Affect Power Output

For full power on the belt, the pulley ratio should be 3 to 1 or less (Fig. 14). Higher ratios (shown) lessen the arc of contact, causing slippage and loss of power.

The arc of contact on the critical smaller pulley increases somewhat if the shafts are moved farther apart. Where a high ratio is required, it is best to use a two-step drive (that is, a countershaft) to avoid the use of excessive single-step ratios or an undersize pulley.

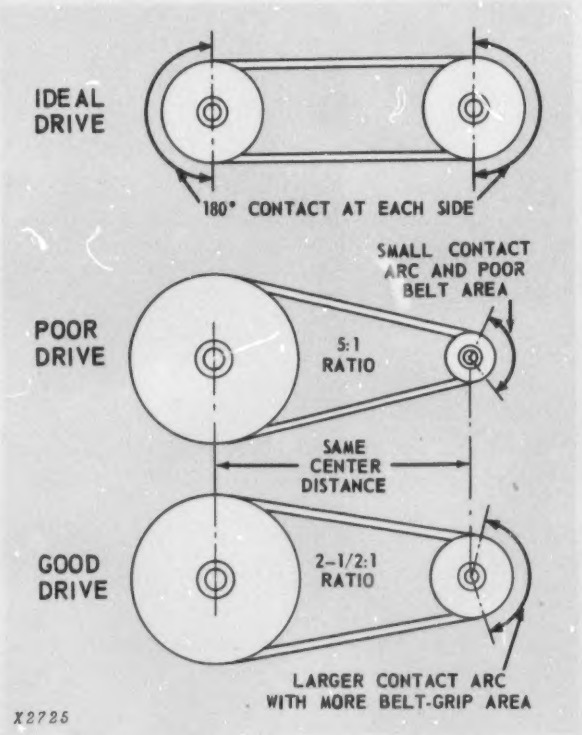

Fig. 14 — How Pulley Sizes Affect Power Output

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RELATIVE OUTPUT SPEED OF BELT DRIVES

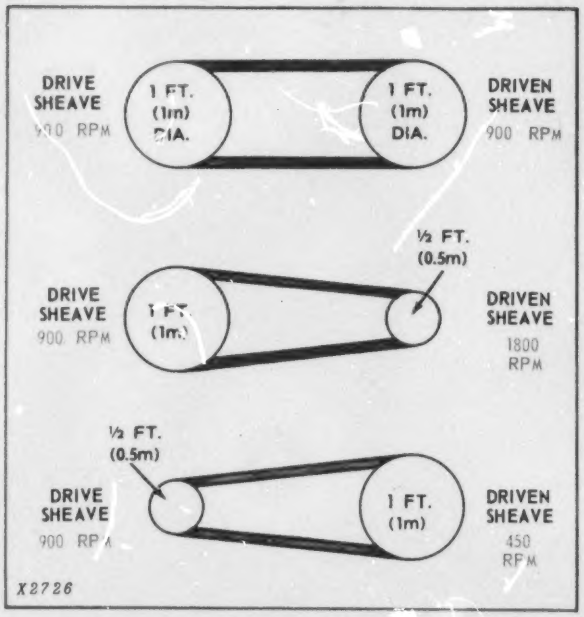

Fig. 15 — Relative Output Speed Of Belt Drives

When two pulleys or sheaves are of the same size (Fig. 15, top) they will rotate at the same speed (rpm).

If we keep the same **drive** sheave but use a smaller **driven** sheave, the driven shaft will turn *faster*.

If we use a smaller **drive** sheave but keep the **driven** sheave the same, the driven shaft will turn *slower*.

The formula for this is:

Diameter Drive Sheave	X	*RPM Of Drive Sheave*	=	*Diameter Driven Sheave*	X	*RPM Of Driven Sheave*

In Fig. 15 we can see how this works (top to bottom):

1 x 900 = *1 x* **900**

1 x 900 = *½ x* **1800**

½ x 900 = *1 x* **450**

VARIABLE-SPEED BELT DRIVES

Variable speed is obtained by changing the effective diameter of the sheave or sheaves during operation.

The sheaves are made up of two halves. By moving the halves together, the driven sheaves become "larger" since the belt now rides higher in the sheave "V" (Fig. 16).

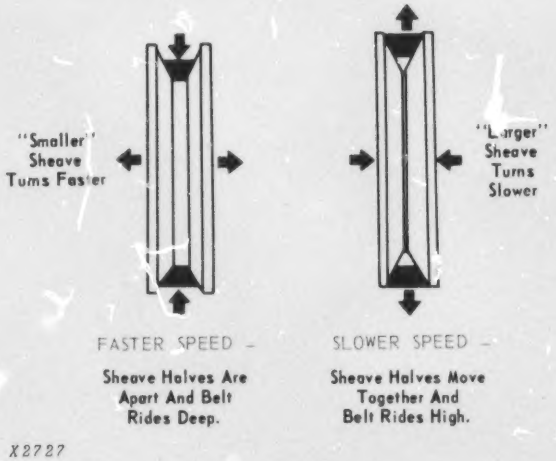
"Smaller" Sheave Turns Faster
"Larger" Sheave Turns Slower
FASTER SPEED —
Sheave Halves Are Apart And Belt Rides Deep.
SLOWER SPEED —
Sheave Halves Move Together And Belt Rides High.
X2727

Fig. 16 — Variable-Speed Belt Drive

When the sheave halves are pulled apart, the driven sheave becomes "smaller" again and the sheave turns at a faster rate.

When the sheave sizes are changed, the belt tension also changes. So there must be a means of "taking up the slack." This may be done in any of these ways:

1) Moving the sheaves closer together or farther apart. (A spring-loaded sheave can do this.)

2) Using an idler on the belt which responds to tension or slackening.

3) Using two variable-pitch sheaves. The sheaves are synchronized so that when one changes its size, the other changes to offset it.

Variable speed drives can be controlled manually or automatically.

ARRANGEMENT OF V-BELT DRIVES

Most common is the **reduction drive,** in which the power source turns faster than the driven shaft.

Less common are these:

- **Speed-up drive,** where the load must run faster than the motor or engine, is considered harder on belts.

- **V-flat drive** is a reduction drive with a V-pulley on the motor and a flat one on the driven shaft. It's used in industry and on some lathe countershafts. To be effective, a V-flat drive should have a big ratio and short shaft spacing, to allow plenty of wraparound on the sheave. The sheave should have a perfectly flat face — not a crowned one.

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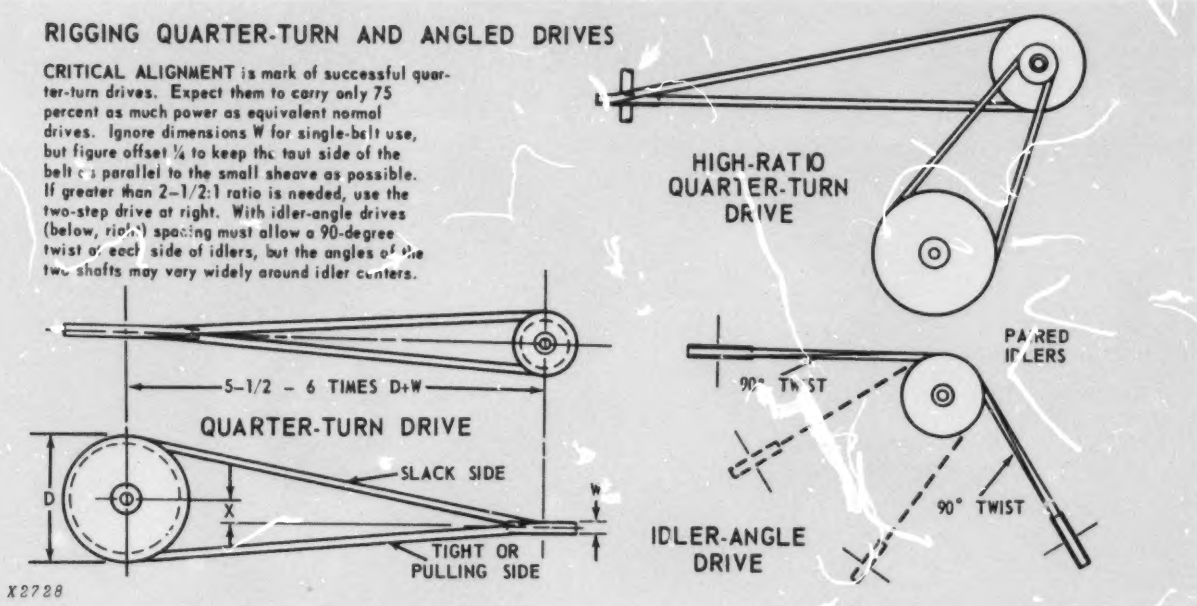
RIGGING QUARTER-TURN AND ANGLED DRIVES
CRITICAL ALIGNMENT is mark of successful quarter-turn drives. Expect them to carry only 75 percent as much power as equivalent normal drives. Ignore dimensions W for single-belt use, but figure offset ¼ to keep the taut side of the belt as parallel to the small sheave as possible. If greater than 2–1/2:1 ratio is needed, use the two-step drive at right. With idler-angle drives (below, right) spacing must allow a 90-degree twist at each side of idlers, but the angles of the two shafts may vary widely around idler centers.
HIGH-RATIO QUARTER-TURN DRIVE
5–1/2 – 6 TIMES D+W
QUARTER-TURN DRIVE
SLACK SIDE
D
X
W
TIGHT OR PULLING SIDE
PAIRED IDLERS
90° TWIST
90° TWIST
IDLER-ANGLE DRIVE
X2728

Fig. 17 — Quarter-Turn And Angled V-Belt Drives

• **Quarter-turn drives** twist the belt through 90 degrees (Fig. 17). Deep-groove pulleys are used, and the shafts are offset to bring the taut or pulling side of the belt more parallel to the groove at the smaller sheave. The belt is mounted so that the tight side is at the bottom — minimizing the sag that tends to pull it off the sheaves. This drive gives only about 75 percent of the power capacity of a normal drive with the same belt-speed-sheave combination.

• **Idler-angle drives** between horizontal and vertical, or otherwise angled, shafts subject the belt to two 90-degree twists (Fig. 17, lower right). Distances from the idlers to both shafts must be generous. Deep-groove idlers are used to prevent the belt from riding itself ragged on shallow groove edges.

• **Dual and multi-drives.** Two 3L belts can transmit more power than a single 5L belt where shaft spacing and pulley sizes are limited. Industrial machines may have multi-grooved pulleys with several ganged V-belts. Belts pulling together should be matched — of the same make and length, or bought as a matched set — and replaced as a group, never singly.

BELT TENSION MECHANISMS

In many successful belt drives, an idler is not necessary, and proper tension can be had by adjusting the position of either the drive unit or the driven unit (Fig. 18, top). (An exception is the variable-load drive, where a spring-loaded idler is still best for longer belt life.)

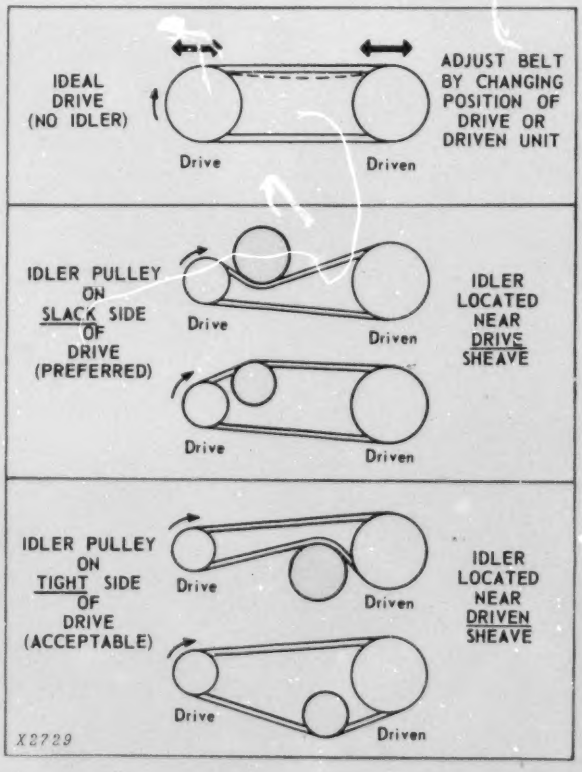

Fig. 18 — Belt Tension Mechanisms

Where the sheaves are not adjustable, a belt tightener with an **idler** pulley or sheave is used (Fig. 18). The idler may be a straight-face pulley running on the outside of the belts or a grooved

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sheave, or straight-face pulley running on the inside of the belts. The arcs of contact on driving and driven sheaves are increased by an idler on the outside and decreased by an idler on the inside.

The idler should preferably run on the **slack** *side of the belts.* A straight-face idler pulley running on either the outside or inside of the belts should be located as close as possible to the sheave delivering (not receiving) the belts (Fig. 18; center). Hence, an idler pulley running on the slack strand of belts should be close to the drive sheave.

If an idler pulley must run on the **tight** strand, it should be close to the driven sheave (Fig. 18, bottom). A grooved idler sheave running on the inside of the belts may be near either sheave but preferably is located to give equal arcs of contact on both sheaves.

Idler diameter should be at least one-third larger than the smallest sheave in the drive when running on the outside of the belts — at least as large as the smallest sheave when running on the inside of the belts.

A *spring-loaded* or weighted idler pulley is sometimes used. This type of idler should be located on the slack side of the drive. It should not be used on a drive where the slack side may temporarily become the tight side.

MAINTENANCE OF V-BELT DRIVES

V-belts are the most common belt drive today, so our main story on maintenance will be for these drives.

MECHANICAL INTERFERENCE

One of the chief advantages of V-belt drives is ease of inspection. By watching and listening, signs of normal wear can be detected.

A belt striking against the belt guard produces an audible "ticking" sound that warns of rubbing contact. This contact can produce rapid wear of the fabric on wrapped belts and will greatly shorten the life of the belt. Where the noise of nearby equipment might drown out the "ticking," routine visual inspection for bent or damaged belt guards will also reveal belt guard contact. Of course, the belt will probably be frayed — another sign of rubbing.

SHEAVE MISALIGNMENT

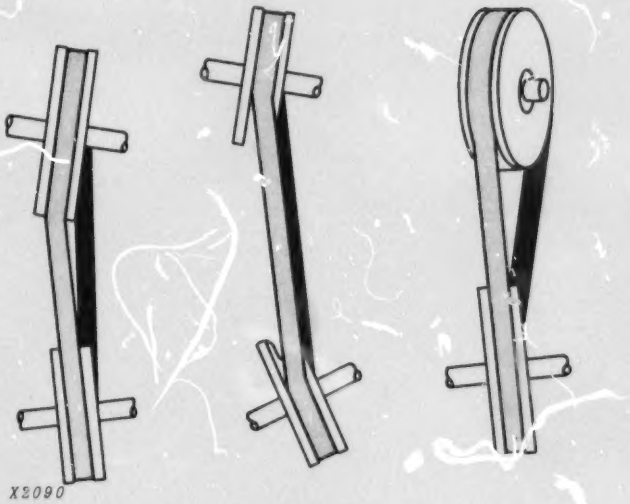

Fig. 19 — Sheaves Not Aligned Can Damage The V-Belt

Sheave misalignment is another problem to watch for during routine inspection. While the misalignment illustrated in Fig. 19 is exaggerated, it does indicate another common cause of shortened belt life.

Sheaves are usually out of line because the drive and driven shafts are not parallel. However, even perfectly parallel shafts do not guarantee sheave alignment.

Fig. 19 shows the most common types of misalignment — all caused by the shafts being inclined out of parallel.

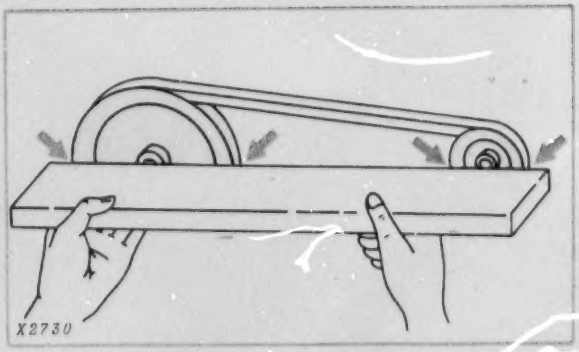

Fig. 20 — Check Alignment Of Sheaves

Possibly the best way to check alignment is to use a straight edge between the sides of the sheaves (Fig. 20).

The straight edge should touch the sheaves at the four arrows. Then rotate each sheave and note

whether the contact of either sheave with the straight edge is disturbed. If so, a shaft is bent or a sheave is wobbling.

Another method is to sight across the edge of the sheave groove in line with the belt. Harmful misalignment will show up as a bend in the belt at the point where it enters or leaves the sheave grooves.

V-belts, because of their flexibility, can tolerate more misalignment than other types of power drives. But there is a point beyond which they should not be misaligned if they are to deliver the service they are designed to give.

MIS-MATCHED BELTS

In multiple drives, the belts must be accurately matched so that the load is evenly distributed among the belts. If the load isn't evenly distributed, the shorter belts will do all the work.

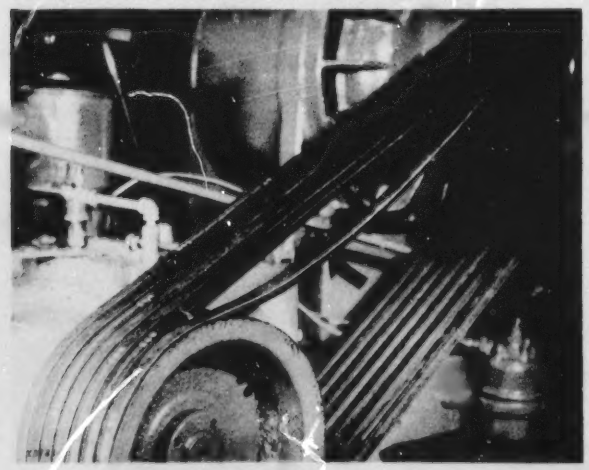

Fig. 21 — Mis-Matched Belts

Fig. 21 shows mis-matched belts. This drive has seven new belts, but one (arrow) is getting a "free ride." Although all belts are new, the outside belt is obviously longer and not pulling its share of the load.

When watching for possible mismatching, look for sagging belts on the tight side of the drive — the side on which the belts approach the motor. If they are even on this side (even though not too even on the slack side) the belts are pulling their fair share of the load.

To insure proper belt matching, V-belts are marked with belt size numbers.

WORN BELTS

All belts and sheaves wear to some degree after they have been in use. As wear occurs the belts ride lower in the sheave grooves. Since center distance has to be increased to compensate for the wear, a worn belt is "longer" than a new belt. (The worn belt also stretches in use.)

It is important, therefore, to **replace the entire set on multiple-belt drives** even though only one belt might fail. If only one belt is replaced, the replacement will in effect be "shorter" than the other belts.

Fig. 22 — Replacing Only One Belt In A Set Means Overloading The New Belt And Underloading The Others

In Fig. 22 only the broken belt has been replaced.

Because the old belts are worn and stretched, the new belt is pulling most of the load. And, since seven belts are obviously needed to meet the horsepower requirements of the application, the overload will considerably shorten the life of the new belt.

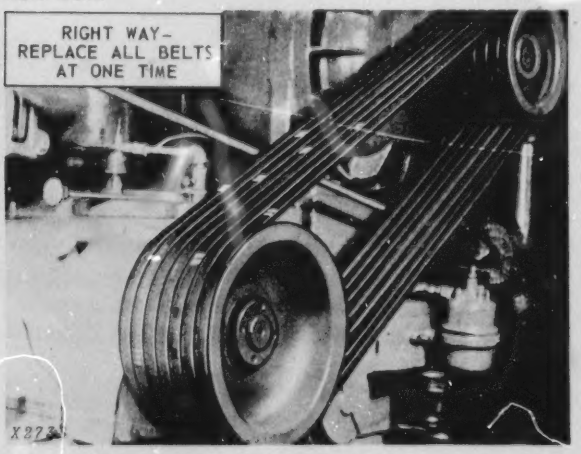

Fig. 23 — Replace All Belts In A Set At One Time As Shown

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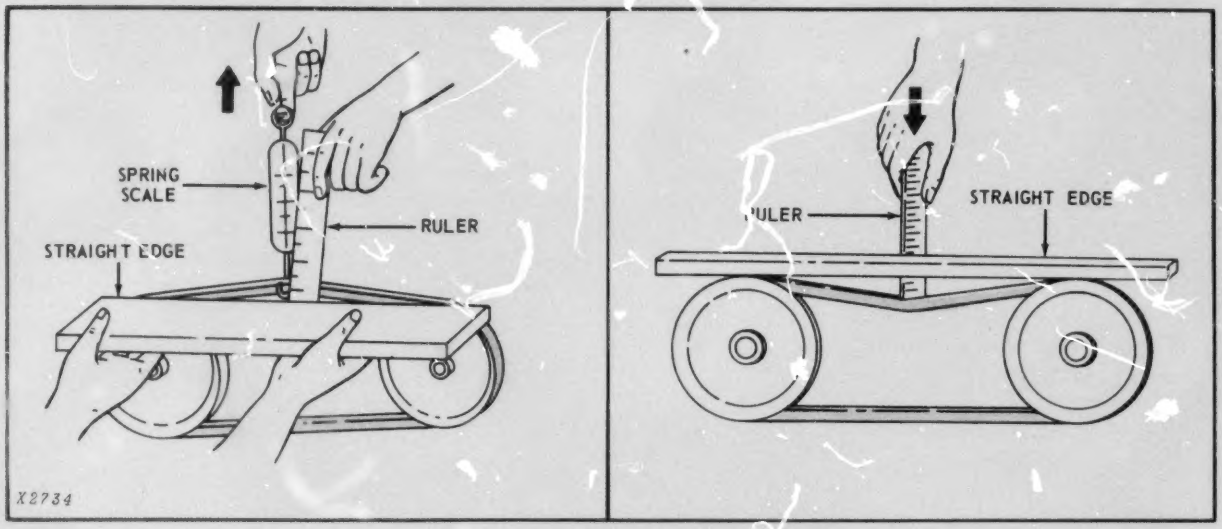

Fig. 24 — Checking Belt Tension

In Fig. 23 all belts in the set have been replaced and each belt is carrying an equal share of the load. When belts pull together like this, they'll give the service they're designed to provide.

It isn't expensive to replace all belts on a multiple drive when only one has failed. It's insurance against forced downtime and lost production.

BELT TENSION

Too little tension will cause slippage or slip-and-grab, causing the belt to break. If the belt does not break, slip will cause excessive cover wear, burned spots, and overheating.

Too much tension will cause belt heating and excessive stretch as well as damage to drive components such as sheaves and shafts. The extra tightness will also place a heavier load on the bearings.

Remember that V-belts should ride on the sides of standard sheaves, not on the bottom of the groove.

Tension on a new belt should be watched *during the first 24 hours of operation*. This is when the initial seating and stretch occurs.

Belt tension is often checked by deflecting the belt on one side with a spring scale (Fig. 24, left). By measuring the deflection at a certain pounds pull, actual belt tension is found. The recommended tension is given in the machine operator's manual.

Another method is to depress the belt halfway between the sheaves using a ruler at right angles to a straightedge (Fig. 24, right).

Tension On Banded V-Belts

On banded V-belts, the only special consideration is that the *entire belt must be deflected uniformly*. This can be done by placing a rigid bar, which will extend across the width of the belt, between the tension tester and the belt.

Tension On Quarter-Turn Drives

On these drives, adjust tension so that when the drive is running, the middle belt on the slack side of the drive will not sag below its groove in the sheave on the vertical shaft.

CAUTION: Never attempt to adjust a belt while it is operating. Keep hands, feet, and clothing away.

BELT SLIP

While loose belts usually cause slippage, the cause may be overload. If belt tension is okay but the belt still slips, overload is the likely problem.

Never attempt to correct slip by using a belt dressing. While reducing slip, the dressing may soften and deteriorate the V-belt.

BELT SQUEAK

Squeak often occurs at idling speeds. It produces a sound very much like the chirping of a bird or a dry bearing and is most prevalent when pressed-steel pulleys are used. Squeak is not unique to certain makes or types of belts. But it is most likely to occur on cold, damp mornings or under dusty conditions.

Squeak itself is harmless, but is frequently mistaken for belt slippage. Consequently, belts are often tightened to a point where they or the bearings are damaged.

Never apply belt dressing or oil as a means of eliminating this noise.

BELT SQUEAL

Squeal is a high-pitched howl or rasping sound that occurs during acceleration or when the belt is near or at overload. It definitely means the belt is slipping and should be investigated. The cause is usually a lack of belt tension.

If the squeal persists after the belts have been checked and tensioned, the drive itself should be checked for overloading. Again, never use belt dressing as a substitute for retensioning the belt.

SHEAVE GROOVE WEAR

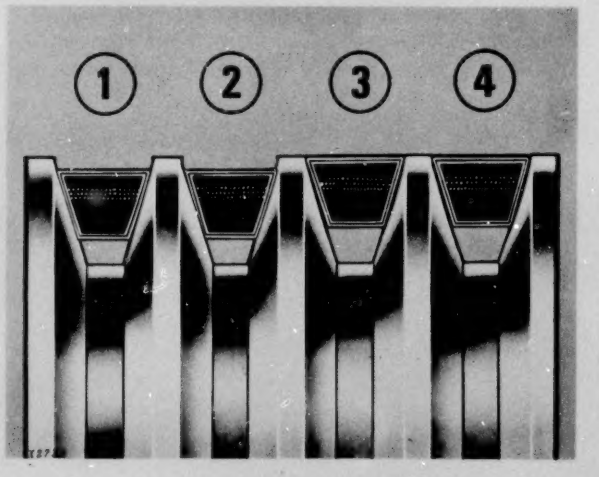

Fig. 25 — Irregular Sheave Grooves

In the four-groove sheave shown in Fig. 25, grooves (1) and (2) are worn much more than the others. This wear allows the belts in the worn grooves to ride **lower** than the rest of the belts and creates the same effect as mis-matched belts.

Also, it causes what is termed "differential driving" — a condition where the belts operate at different speed ratios between the drive and driven units. In such a drive, the belts actually "fight" each other because some of them are trying to travel faster than others.

The wedging principle of V-belt drives makes it vital to keep the sheave groove sidewalls perfectly straight.

When the groove walls are dished out, the belt's wedging action is reduced. The gripping power is reduced and — in extreme cases — slippage occurs and belt life is greatly shortened.

When mis-matched belts are spotted in a multiple drive, the sheave grooves should be examined for excessive wear. On banded V-belts, if the tie band is separating from the belts, this may also mean worn sheave grooves.

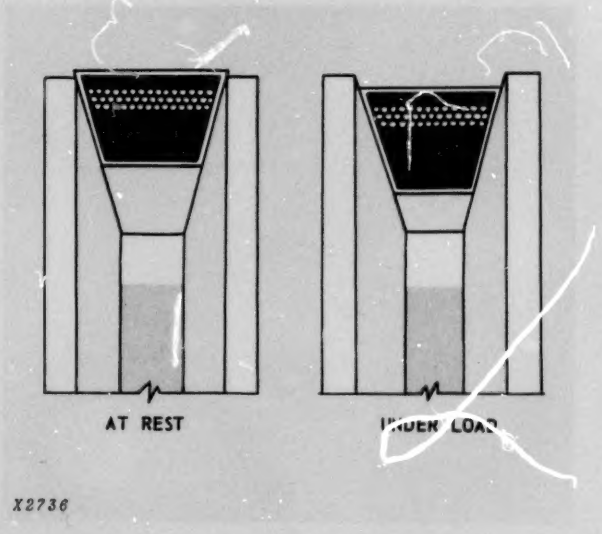

Fig. 26 — Correct Position Of V-Belt In Sheave Groove (R.M.A. Standard Sheave)

Because of slight variation in V-belts and sheave grooves, the riding position of new belts in new sheaves will vary. In a standard sheave, it will vary from $\frac{1}{16}$-inch (1.6 mm) above the top of the grooves to $\frac{1}{16}$-inch (1.6 mm) below the top (Fig. 26). However, for a given multiple-groove sheave, the riding positions of the belts should be uniform.

A new belt that rides lower than the other belts in a drive may mean that the sheave groove sidewall is "dished out" (Fig. 27, next page).

SHINY SHEAVE GROOVE BOTTOMS

In standard sheaves, a shiny groove bottom is a sign that the belt, or sheave, or both are badly worn and the belt is bottoming in the groove. This causes the belt to lose its grip and waste power.

Worn sheaves or shiny sheave groove bottoms will usually show up first on the smaller sheave of the installation.

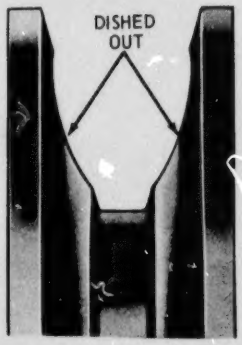

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Fig. 27 — Sheave Grooves "Dished Out" By Wear (Replace Sheaves)

WOBBLING SHEAVES

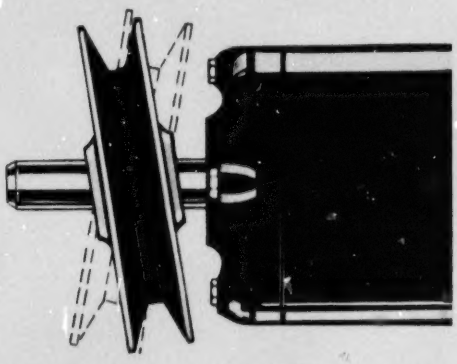

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Fig. 28 — Wobbling Sheave

Wobbling sheaves are another cause of shortened belt life. A wobbling sheave (Fig. 28) whips the belt from side to side, subjecting it to a lateral strain which produces rapid sheave and belt wear. A wobbling sheave also transmits vibrations to the machine.

Sheave wobble is caused by improper installation of the sheave on the shaft, a worn or damaged bushing or sheave hub, or by a bent shaft. Sheaves must be installed so they run true on the shaft to insure maximum belt life.

A sheave that wobbles badly enough to require adjustment can be readily spotted by visual inspection.

DAMAGED SHEAVES

Sometimes sheaves are damaged as shown in Fig. 29. Cast sheaves may become chipped; pressed steel sheaves can get bent.

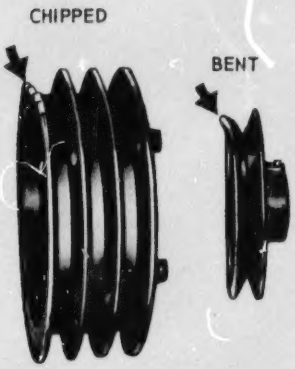

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Fig. 29 — Damaged Sheaves

Regardless of the type of damage to the sheave, damaged sheaves always produce rapid belt wear. The only way to prevent short belt life is to correct the sheave condition immediately.

REPLACING SHEAVES

If a sheave is excessively worn, bent, cracked, or broken, replace it as follows:

1. Select replacement sheave. Sheave must have the *same groove and shaft diameter as the old one.* It also must have the *same outside diameter.* Changing diameters will call for a different length of belt and also will change the speed of the drive.

2. Remove shields.

3. Loosen tension and carefully remove belts.

4. Loosen sheave on shaft. You may have to loosen a set screw and remove a key, loosen a sheave flange bolt, remove a split bushing, or remove a retainer nut. On some installations you may have to remove a bearing or two before removing the sheave.

5. On sheaves with split-type bushings, insert bolts in threaded holes and tighten evenly until sheave comes off.

6. For other fasteners, you may be able to pry the sheave off the shaft with a bar. Pry from first one side and then the other (Fig. 30). Do not let the sheave fall freely on a hard surface. Never pound on a sheave with a hammer. Many are metal castings and are easily broken.

20

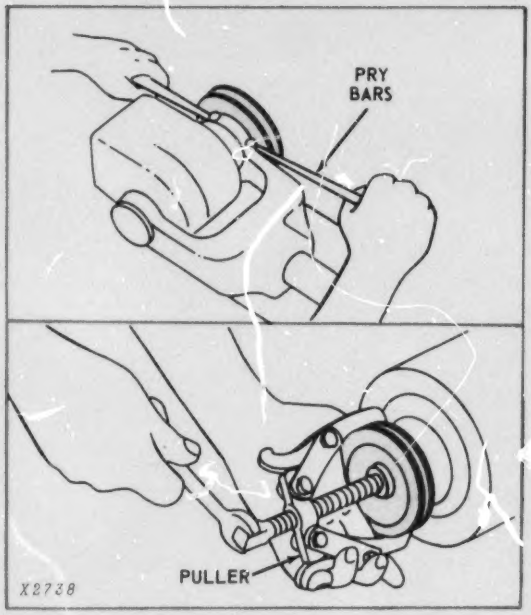

Fig. 30 — Removing Sheaves

7. If you cannot pry the sheave off, use a puller (Fig. 30).

8. A sheave can be broken with a puller if you are not careful. Tighten the puller, then pound on the end of the puller to jar the pulley loose.

9. Replace with new sheave(s). Sheave should go on by tapping the hub with a plastic or rubber hammer.

10. Check sheave alignment (see page 12).

11. Tighten sheave on shaft.

OVERHEATED BELTS

V-belts are composed mainly of rubber — and heat is the natural enemy of rubber.

When the drive is open or ventilated, the temperature is usually not sufficient to affect the belts.

Under field conditions, belts operating in temperatures of less than 180°F. (84°C) are not materially affected. Temperatures in excess of 180°F. (84°C) may harden the belt, causing it to crack and stretch. To prevent this, be sure that screens and shields are kept clean for full ventilation.

Fig. 31 shows a belt damaged by excessive heat. It appears cracked or checked on the bottom edge and should be replaced.

Special belts are available for use where heat is a problem.

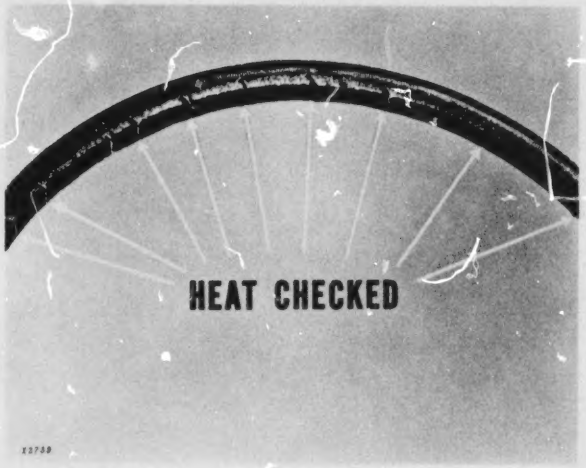

Fig. 31 — Belt Ruined By Too Much Heat

OILY OR GREASY BELTS

Fig. 32 — Belt Ruined By Oil And Grease Soaking

Oil or grease if allowed to soak into the rubber (Fig. 32) causes a V-belt made of natural rubber — or synthetics — to become soft, to swell and to deteriorate very rapidly.

When oil or grease is found on a belt, wipe it off with a clean cloth dampened with a detergent solution. Then wipe dry with a clean dry cloth (Fig. 33).

For naturally oily or greasy operations, oil-resistant belts can be installed.

CAUTION: Never try to clean a belt while it is operating.

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Fig. 33 — Clean Belts Of Oil And Grease Promptly

INSTALLING V-BELTS

A belt found turned over in the pulley groove should be replaced. Flip-over usually means one or more of the cords in the strength section is broken.

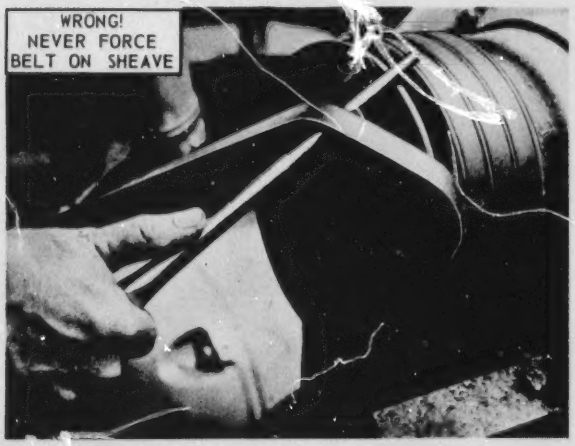

Fig. 34 — Never Force A V-Belt Onto A Sheave

Broken cords can result from prying belts into sheaves without loosening the idler mounting bolts (Fig. 34).

The proper method of installing a V-belt is to loosen the mounting bolts, slide the drive forward and drop the belt over the sheave.

CAUTION: Keep all belt guards and shields in place.

SIGNS OF IMPROPER V-BELT INSTALLATION

- *Belt stretched beyond take-up*
- *Belt slips*
- *Belt fails rapidly for no visible reason*
- *Belt rolls over*
- *Belt cut on bottom*

STORING V-BELTS

Proper belt storage is important for both new belts and for those on the machine.

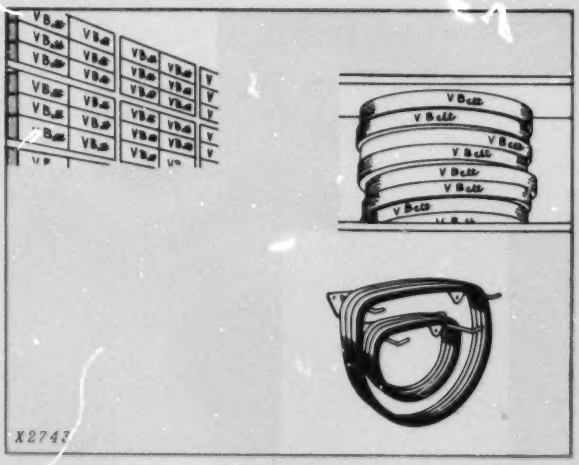

Fig. 35 — Storing Belts In The Shop

Storage In The Shop

New belts should be stored as follows to keep them factory-fresh:

1. Store belts in a clean, cool, dry place. Shrinkage or deterioration may occur if belts are piled on damp floors or stored near radiators.

2. Keep belts away from heat and direct sunlight.

3. Do not place in bins for long periods which might distort the shape of the belt.

4. Do not hang belts on small pegs or nails. Heavy belts could be weakened due to distortion. To prevent this, hang belts across two pegs (Fig. 35).

5. Do not break matched sets — keep intact.

Storage On The Machine

If a machine is stored for a long period, observe these rules:

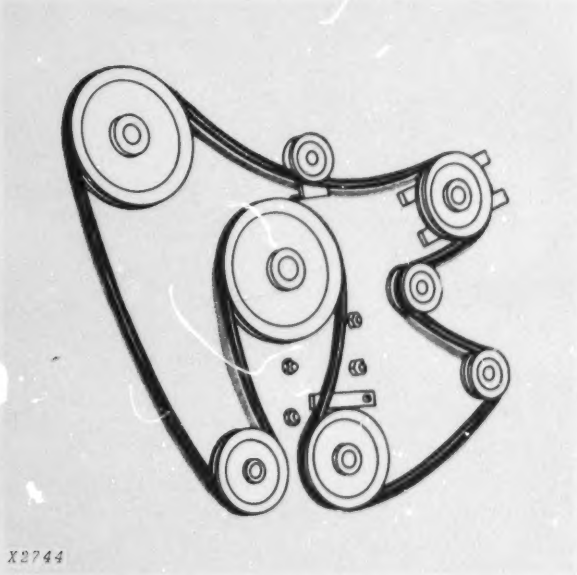

Fig. 36 — Loosen All Belts If Stored On The Machine In Off Seasons

1. If belts are not to be removed, relieve belt tension by loosening all tighteners (Fig. 36). This is necessary to prevent the belt from "setting" or developing unequal stresses that might lead to early failure.

2. If possible, remove all belts. Thoroughly clean them, then store in a cool, clean, dry place.

3. If the belts are removed, coat sheave grooves with an anti-rust compound or grease prior to storage. Be sure to remove such rust preventives before installing the belts and starting the machine. Sheave grooves can also be protected with a section of discarded belt tied in place.

4. Protect all movable or sliding parts of variable-speed drives by lubricating thoroughly to prevent corrosion due to moisture.

SUMMARY: MAINTENANCE OF V-BELTS

1. Listen for "ticking" sounds — they mean interference with belts.

2. Replace all belts in a matched set at one time.

3. V-belts stretch most during their first 24 hours of operation. Check tension and keep belts tight.

4. Never attempt to correct belt slippage by using a belt dressing.

5. If belts slip even when properly tensioned, check for overload, worn sheave grooves, or oil or grease on belts.

6. Never pry a V-belt or force it into the sheave groove. Loosen the tightener before installing the belt.

7. A belt which has operated while rolled over in the sheave groove is probably damaged — replace it.

8. Store belts in a cool, dry place. If stored on a machine, be sure to relieve all belt tension.

9. Never attempt to check or adjust belts while they are running.

MAINTENANCE OF FLAT BELTS

Many of the maintenance tips for V-belts also apply to flat belts. Here are some other rules:

1. Some flat belts, usually leather or canvas, may require belt dressings to prevent deterioration.

2. Flat belts normally need more tension than V-belts.

3. Pulley alignment is even more important with flat belts than for V-belts because flat belts can run off the pulley easier.

4. To install flat belts, move the power unit forward, place the belt on the pulleys, and back up carefully to tighten the belt. Start the belt slowly to make sure it is running straight before increasing the speed.

5. Never force a belt off a moving pulley.

WEAR ON V-BELTS

First of all, remember that V-belts transmit power by friction and a *wedging* action between the sides of the belt and the inside walls of the sheave groove. This is where to look for signs of wear.

All belts and sheaves wear in use. Normal wear can be recognized as **even wear** — both on the belt and the sides of the sheave. It is **unusual wear** which you should look for and correct.

Many belts are reported as being defective but, upon closer examination, the failure has been traced to a bad sheave, misaligned drive or some other fault of a mechanical component of the machine. These problems were covered above under "Maintenance of V-Belts."

Now let's look at failures of the belt itself.

EXAMPLES OF UNUSUAL V-BELT WEAR

The photographs in Fig. 37 will help you to recognize some of the signs of unusual V-belt wear.

Some of these belts are ruined beyond use (1, 5, 7) while others still have considerable service life left (4, 6).

Base Cracking

Excessive cross-cracking on the base of a belt having little or no side wear ("1", Fig. 37) indicates the belt has been run a relatively short time and therefore must be defective. Except for the cracking, it is in nearly new condition.

If the sidewalls show three or four seasons use, the belt shouldn't be classified as being defective ("2", Fig. 37). Actually, the cracks in the base of this belt show that it has been exposed to weather until the inner fabric is beginning to rot.

Fabric Rupture

This belt (3) is not defective. This type of rupture can be caused by operating a belt over badly worn sheaves, too much tension which forces the belt down into the grooves, or foreign objects falling into the sheave groove while the drive is operating.

In these cases, check the condition of the sheaves. Avoid prying belts onto sheaves.

Cover Tear

Belt No. 4 is an example of damage caused by the belt accidentally coming into contact with some part of the machine, tearing the cover. It is no fault of the belt or its construction.

In many cases, such failure is due to belts running too loose, allowing them to "throw-out" centrifugally so that they rub on parts of the machine. Proper belt tension prevents this from happening.

NOTE: A slight raveling of the belt covering at the splice does not indicate premature failure. The raveling should be cut off if the covering peels at the lap.

Slip Burn

This belt (5) has been ruined by being operated too loose. The belt slipped under load, and when it finally grabbed, it snapped.

In these cases, check belt tension more often. Turn drives over by hand to make sure they are free. Clear machine of any loads before stopping to avoid overloading drives when starting up again.

Gouged Edge

Except for the gouged edge, the entire circumference of this belt (6) is in new condition. Damage was caused by either a damaged sheave or interference with some part of the machine.

In this case, check the condition of the sheaves. Make sure belt does not rub on any part of the machine while operating.

Burn Due To Locked Drive

The general appearance of this belt (7) indicates that it has been properly tensioned. Apparently the drive locked and the belt slipped on the sheave, resulting in a burned area.

Prevent drives from locking by checking the tension of any belts in the drive train. Avoid overloading and plugging the machine. Never attempt to run a plugged machine without first cleaning it out. Lubricate the machine at the specified intervals to prevent bearing seizure.

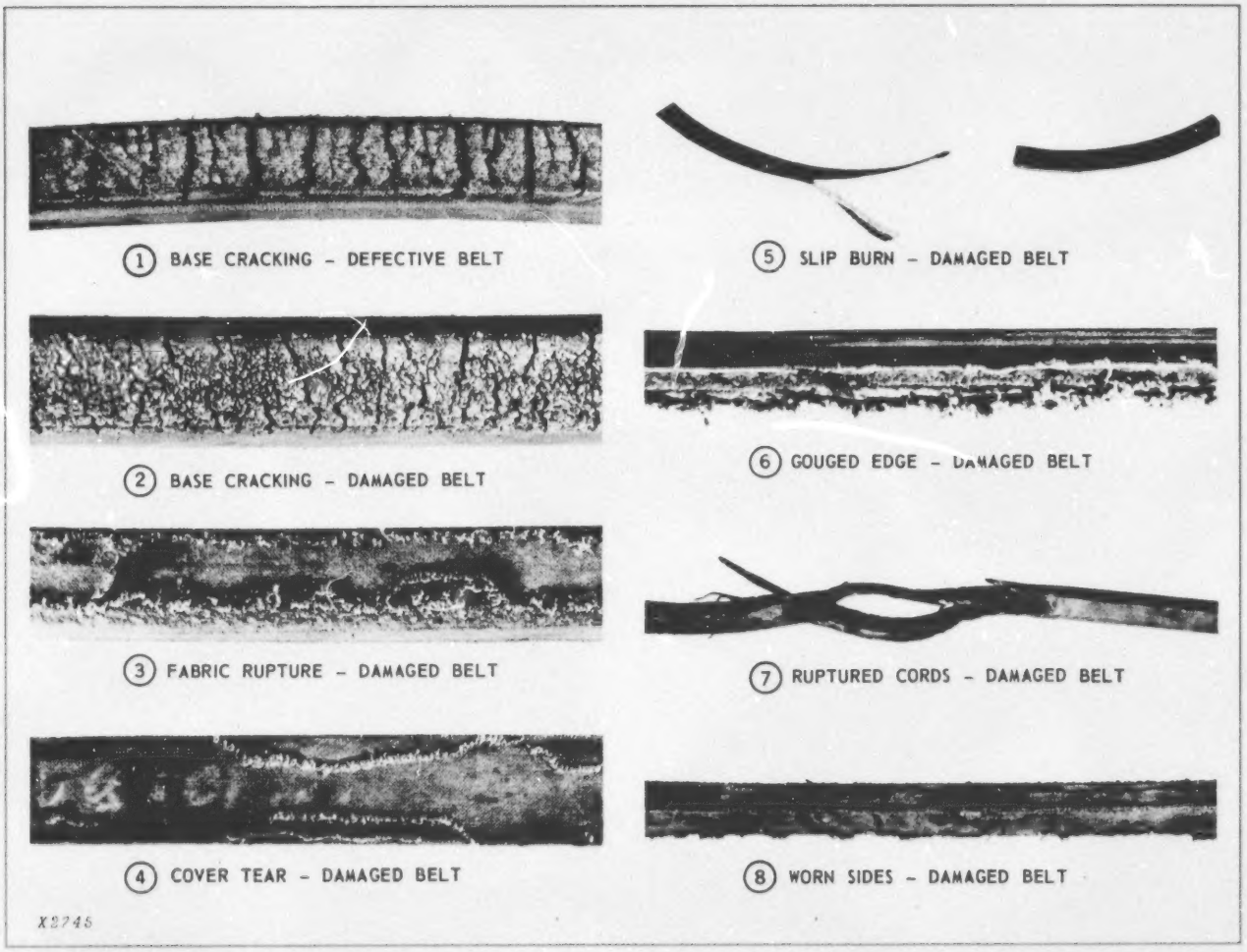
1 BASE CRACKING - DEFECTIVE BELT
2 BASE CRACKING - DAMAGED BELT
3 FABRIC RUPTURE - DAMAGED BELT
4 COVER TEAR - DAMAGED BELT
5 SLIP BURN - DAMAGED BELT
6 GOUGED EDGE - DAMAGED BELT
7 RUPTURED CORDS - DAMAGED BELT
8 WORN SIDES - DAMAGED BELT
X2745

Fig. 37 — Examples Of Wear On V-Belts

Worn Sides

No. 8 is a typical example of a badly worn belt resulting from long operation without enough tension. The sides are worn and the entire circumference is slightly burned.

To prevent this, check belt tension more often. Also check sheaves for misalignment.

DEFECTIVE V-BELTS

While the examples shown in Fig. 37 illustrate only one belt (No. 1) that can be termed **defective**, some other types of defective belts not easily shown by photographs are as follows:

Excessive Stretch

A belt that stretches excessively is one that stretches beyond the tightener adjustment provided to take up normal belt stretch. This will usually occur within the warranty period.

Lumpy Belts

Lumpy belts usually occur and are more noticeable on variable speed drives and other high speed belt installations. The result is excessive vibration.

Internal Cord Failure

Failure of one or more of the internal tension cords will result in the belt rolling over on the sheaves. (Cords can be broken by prying a new belt over sheaves.)

Improper Length

It is possible for belts either too long or too short to be shipped accidentally in repair parts orders. Such belts would not pass the line run-in for new machines at the factory.

WEAR ON BANDED V-BELTS

Banded V-belts have some wear problems which are unique, so let's look at them in a separate story below.

ONE BELT RIDING OUTSIDE SHEAVE GROOVES

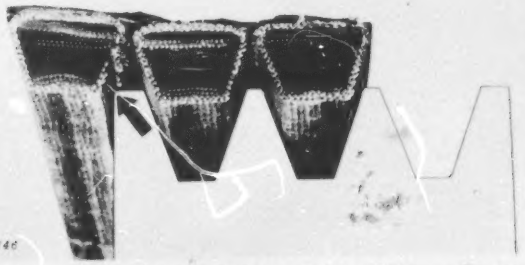

Fig. 38 — Banded V-Belt Riding Outside Of Sheave Grooves

Trouble Area And Observation	Cause	Remedy
Banded belt with one strand riding outside sheave grooves (Fig. 38). *NOTE: Distinct groove in sidewall of outside belt.*	Possible misalignment, lack of tension or foreign object forced belt from sheave grooves.	Properly align drive, retension and remove any interference.

NOTE: If above belt were permitted to run in this position, progressive failure would result as shown in following two illustrations (Fig. 39 and 40).

SEPARATION OF ONE BELT FROM BAND

Trouble Area And Observation	Cause	Remedy
Outside belt and belt adjacent to it have started to separate from the band (Fig. 39).	Banded belt has jumped one groove, forcing outside belt out of sheave. Improper tension misalignment or foreign object struck belt and forced it from normal path.	Replace complete banded belt and seat properly in aligned grooves. Tension properly.

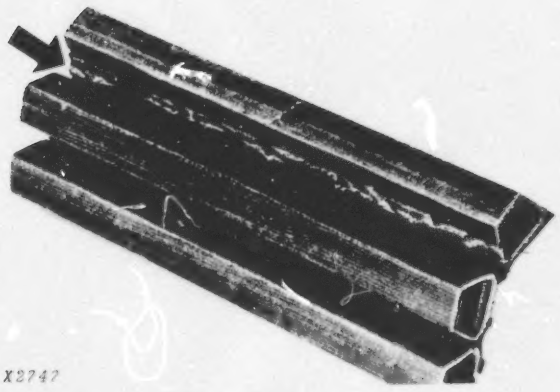

Fig. 39 — Separation Of One Belt From Band

SEPARATION OF ALL BELTS FROM BAND

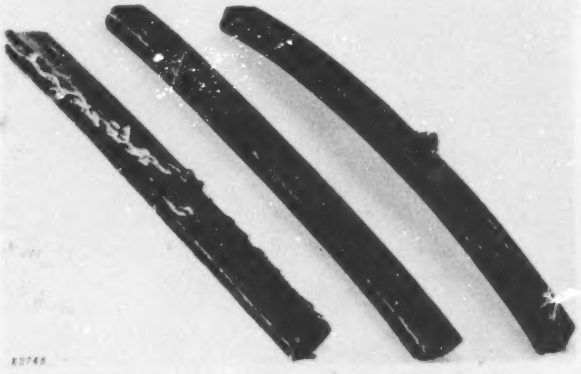

Fig. 40 — Separation Of All Belts From Band

Trouble Area And Observation	Cause	Remedy
Belts have separated completely from tie band (Fig. 40).	Riding outside of sheave grooves.	Proper maintenance of drive with installation of belt.

SHORT BELT LIFE — BOTTOMS OF BELTS CRACKING

Trouble Area And Observation	Cause	Remedy
Bottom of belts cracking (Fig. 41).	Belt running on too-small sheaves. Belt slipping causing heat build-up and gradual hardening of undercord.	Consider minimum diameters for drives, drive and idler sheaves, and pulleys. Check belt tension.

Fig. 41 — Short Belt Life — Bottom Of Belts Cracking

SHORT BELT LIFE — TOP OF BAND FRAYED

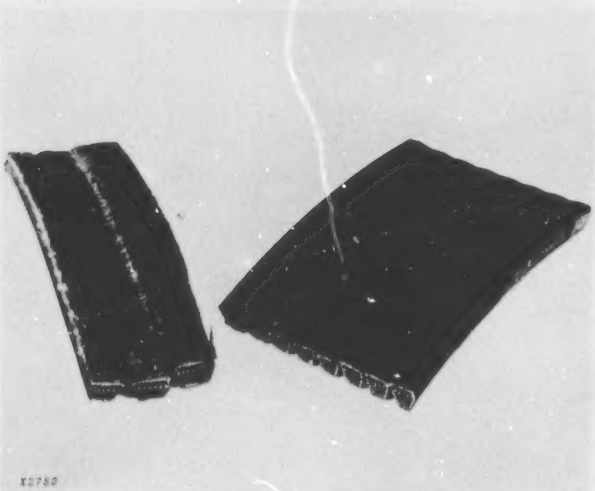

Fig. 42 — Short Belt Life — Top Of Band Frayed Or Damaged

Trouble Area And Observation	Cause	Remedy
Top of tie band frayed or damaged (Fig. 42).	Obstruction on machine interfering with normal operation of belt.	Realign drive and remove obstruction.

SHORT BELT LIFE — BAND SEPARATING FROM BELTS

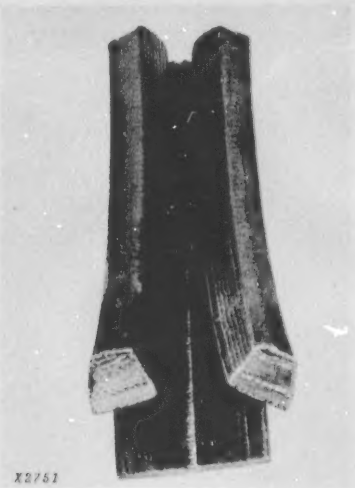

Fig. 43 — Short Belt Life — Band Separating From Belts

Trouble Area And Observation	Cause	Remedy
Tie band separating from belts (Fig. 43).	Worn sheaves.	Gauge sheave grooves and replace with standard-groove sheaves.

SHORT BELT LIFE — HOLES OR BLISTERS IN TIE BAND

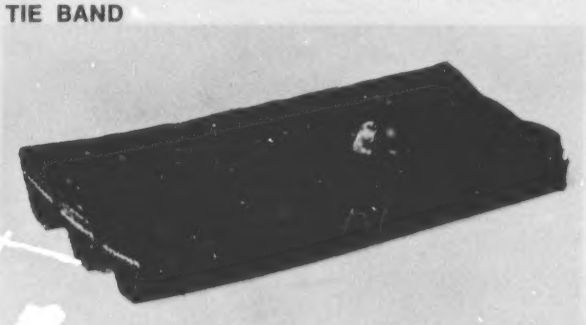

Fig. 44 — Short Belt Life — Holes Or Blisters In Tie Band

Trouble Area And Observation	Cause	Remedy
Large holes or blisters appear on tie band (Fig. 44).	Trash and foreign material accumulating between belts.	Shield drive.

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WEAR ON FLAT BELTS

Common wear on flat belts is shown in Fig. 45 and explained below.

FLAT BELT TEARS

An improperly aligned tightener pulley caused this drive flat belt to climb the inner edge of the engine drive pulley, tearing the edge of the belt (Fig. 45, top). One of these tears eventually caused the belt to tear completely through.

Check belt and pulley alignment to prevent unnecessary wear on the edges of the belt.

FLAT BELT BURN

The shiny appearance and the badly burned area (Fig. 45, bottom) were caused by operating this drive belt too loose. Note the notch in the edge of the belt (arrow) where it slid sideways against the flange of the drive pulley while slipping and burning the center section. Similar damage can result from attempting to unload a machine with power without first cleaning it out.

Check belt tension periodically to prevent this type of belt damage.

FLAT BELT TEARS – DAMAGED BELT

X2753 FLAT BELT BURN – DAMAGED BELT

Fig. 45 — Examples Of Wear On Flat Belts

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TROUBLE SHOOTING BELT DRIVES (Causes and Suggested Corrections)

1 RAPID V-BELT WEAR	**Rubbing Belt Guard** • Check guard clearance	**Worn Sheave Grooves** • Check groove sidewalls	**Sheave Diameter Too Small** • Use larger sheave	**Overloaded Drive** • Reduce loads	**Mismatched Belts** • Replace with matched set	**V-Belt Slipping** • Increase tension
	Sheave Misalignment • Correct alignment	**Damaged Sheaves** • Replace sheaves	**Improper V-Belt Installation, Belts Pried over Sheaves** • Determine how belt was installed (Replace belts do not pry belts over sheaves)	**Belts Improperly Stored or in Storage Too Long** • Use new set of V-belts	**Replacing One Belt in Multiple Drive** • Replace complete set of V-belts	
2 V-BELTS TURNED OVER IN SHEAVE GROOVE	**Broken Cords in V-Belts, Belts Pried over Sheaves** • Determine how belt was installed (Replace belts, do not pry belts over sheaves)	**Overloaded Drive** • Reduce loads	**Defective Cord Construction in V-Belt** • Check for narrow spot in belt. Replace belts	**Impulse Loads** • Use banded V-belts or spring-loaded idlers		
3 V-BELT SLIPPAGE	**Lack Of Tension** • Increase tension	**Overloaded Drive** • Reduce loads	**Sheave Worn, Belts Bottoming in Groove (Shiny sheave groove bottom)** • Replace or rework sheave	**Oily Drive (Leaking Bearings)** • Correct unnecessary oil or grease condition	**Sheave Grooves Too Wide, Belts Bottoming in Grooves** • Use larger belt section or replace sheaves	**Oily Drive Conditions** • Clean up drive or use chains
4 V-BELT SQUEAL	**Lack of Tension** • Increase tension	**Overloaded Drive** • Reduce loads	**Insufficient Arc of Contact** • Increase center distance between sheaves			
5 CHECKED OR CRACKED V-BELTS	**Belt Slippage** • Increase belt tension	**Excessive Heat** • Provide adequate Ventilation and check belt tension				
6 REPEATED V-BELT FRACTURE	**Shock Loads** • Increase V-belt tension. Heavier drive may be required	**Heavy Starting Loads** • Increase V-belt tension. Heavier drive may be required	**Improper V-Belt Installation, Belts Pried Over Sheaves** • Determine how belt was installed (Replace belts, do not pry belts over sheaves)			
7 FLAT BELT DRIVE OPERATING IMPROPERLY	**Insufficient Tension Causing Belt Slippage** • Increase tension	**Pulley With Excessive Crown** • Remove excessive crown	**Too-Long Center Distance (Belts Run Off)** • Use shorter center distance between pulleys	**Slippage on Flat Pulleys** • Shorten center distance or replace flat with V-belt	**Excessive Shock Loads (Belts Run Off)** • Use V-belts	

TEST YOURSELF

QUESTIONS

1. What are the three basic types of belts?

2. How are V-belts driven?
   a. From the *bottom* of the sheave groove.
   b. From the *sides* of the sheave groove.
   c. *Both* of the above.

3. True or false? "When a V-belt runs around its sheaves, the bottom of the belt stretches."

4. Why do pulleys for flat belts have a crown or raised center for the belt surface?

5. If the *drive* pulley has a diameter of one foot (304.8 mm) while the *driven* pulley has a diameter of ½ foot (152.4 mm), which shaft will turn twice as fast as the other?

6. True or false? "Always replace all belts at one time on a multiple-belt drive."

7. If a belt squeals, what are the two most likely causes?

8. True or false? "A good belt dressing is the best way to reduce slippage of V-belts."

9. When a machine is stored, how should the belts be tensioned?

(Answers on page 53).

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CHAINS / PART 2

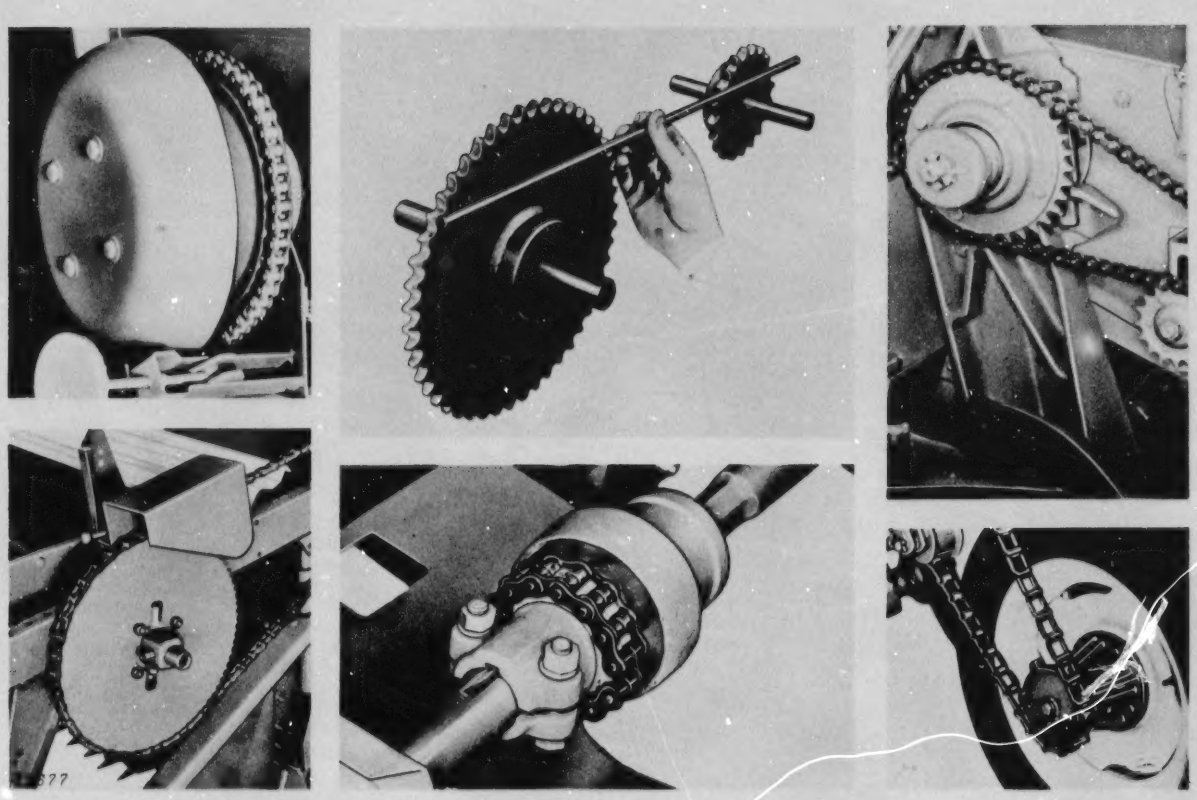

Fig. 1 — Chain Drives

INTRODUCTION

Chain drives are a form of flexible gearing. The chain is like an endless gear rack, while the sprockets are similar to pinions or driven gears.

Chain drives are similar to belt drives except that they are less flexible but more powerful. They also eliminate the slippage that belt drives may give.

Chain drives consist of one or more sprockets and an endless **chain** (Fig. 2).

PRINCIPLES OF CHAIN DRIVES

1. Chain drives are normally used to transmit power from one rotating shaft to another.

2. The links of the chain mesh with the teeth of the sprockets and maintain a positive speed ratio between the driving and driven sprockets.

3. Sprockets connected to the same side of a chain revolve in the same direction. If connected on reverse sides, they revolve in opposite directions.

4. Sprockets for roller chain drives must have at least twelve teeth to avoid excessive wear, noise, and vibration.

5. If the chain has an even number of pitches (spaces between links), the sprockets have an odd number of teeth, and vice versa. This prevents a single link from contacting the same tooth each time, causing uneven wear and vibration.

6. A small sprocket causes sharper bending of the chain and more wear.

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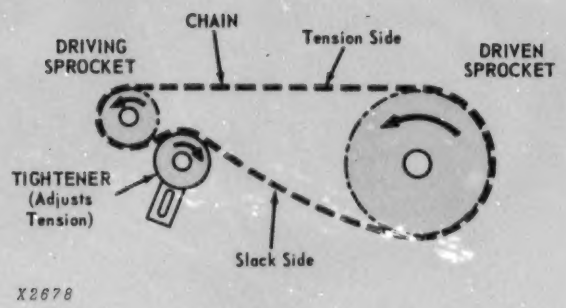

Fig. 2 — Parts Of A Chain Drive

7. Short links bend less and should be used on smaller sprockets.

8. Chains may be installed in single or multiple strands, depending on the load.

9. Chain slack must be adjusted from time to time by moving one of the main sprockets or a chain tightener (Fig. 2).

10. Horizontal chain drive should have the slack side on the bottom if possible.

11. Tighteners or idlers should be on the slack side of the chain.

ADVANTAGES OF CHAINS (As Compared With Belts)

1. *Chain drives do not slip or creep as do belt drives. As a result chains maintain a positive speed ratio between the driving and the driven shafts and are more efficient since no power is lost due to slippage.*
2. *Chain drives are more compact than belt drives. For a given capacity, a chain will be narrower than a belt, and the sprockets will be smaller in diameter than pulleys.*
3. *Chains are easier to install.*
4. *Chains can operate at higher temperatures than belts.*
5. *Chain drives are usually more practical for very low speeds.*
6. *Chains do not deteriorate due to age, oil, grease, or sunlight but they may rust if not protected.*

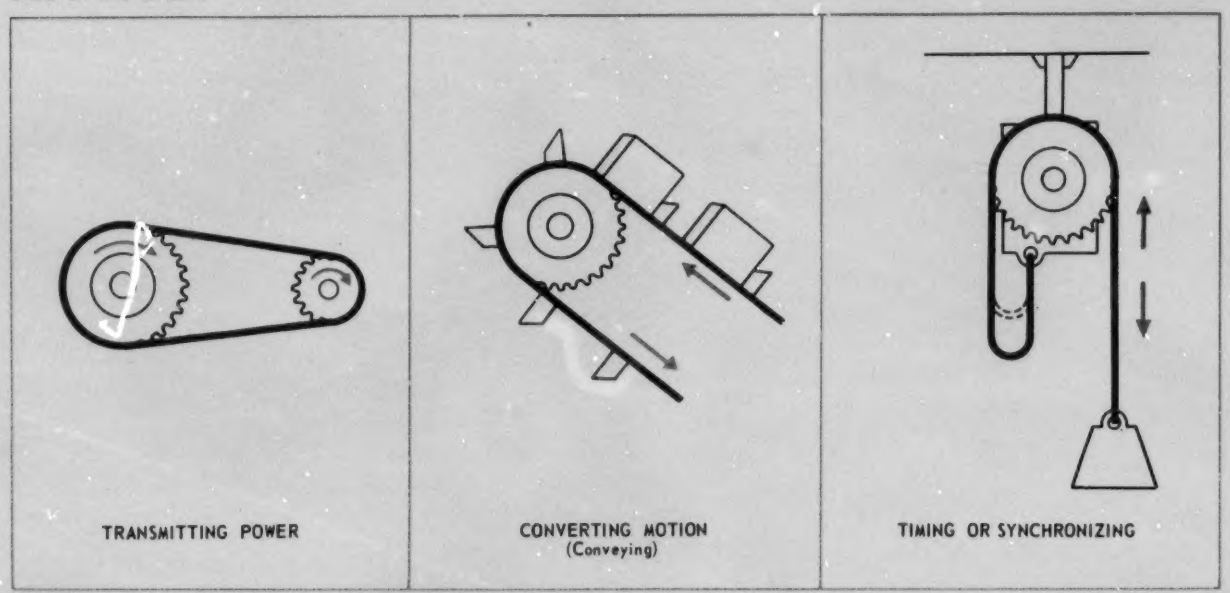

Fig. 3 — Use Of Chains

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DISADVANTAGES OF CHAIN DRIVES

1. *Chain drives are fairly noisy.*
2. *Chains usually require frequent lubrication.*
3. *Most chains will accept very little misalignment.*
4. *Chains cannot normally be used where the drive must slip. (There are exceptions.)*

USES OF CHAINS

The three basic jobs of chains are:

- **Transmitting power**
- **Converting motion**
- **Timing or synchronizing**

In TRANSMITTING POWER, chains and sprockets are used as flexible *gearing* to transmit torque from one rotating shaft to another (Fig. 3, left).

In CONVERTING MOTION, chains are used to *convey* materials by sliding, pushing, pulling, or carrying (Fig. 3, center).

In TIMING or SYNCHRONIZING, chains are used as devices to *synchronize* movements such as valve timing in automobiles or raising loads on an overhead chain hoist (Fig. 3, right).

TYPES OF CHAINS

There are six major types of chains used in chain drives:

- **Roller chain**
- **Rollerless chain**
- **Silent chain**
- **Detachable link chain**
- **Pintle chain**
- **Block chain**

All these chains are shown in Fig. 5 on the next page. Now let's look at each one in detail.

ROLLER CHAIN

Roller chains are widely used for moderate speeds and heavy loads, and where average wear is expected. Standard pitch chains are used for speeds up to 4500 feet per minute (1370 m/min), while extended pitches are designed for slower speeds. See Fig. 8 for explanation of "pitch."

Construction

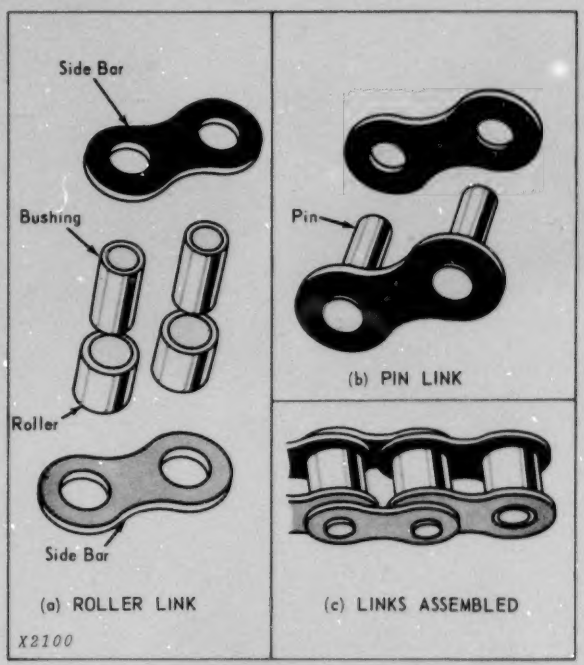

Fig. 4 — Construction Of Roller Chain

Standard roller chain is made up of alternate roller links and pin links (Fig. 4). Roller links have two side bars, two bushings, and two rollers, while pin links have two side bars and two pins. Pins are usually in rivets with cotter pins for connecting, although the complete chain may be joined by removable pins.

The side bar of the roller chain determines the pitch (or angle) of the chain. Double pitch or extended pitch roller chain has the same parts as the standard-pitch chain, but the side plates have twice the pitch (see Fig. 8). Double pitch chains are lighter in weight and less expensive.

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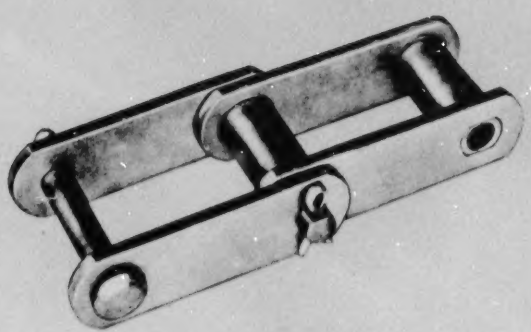
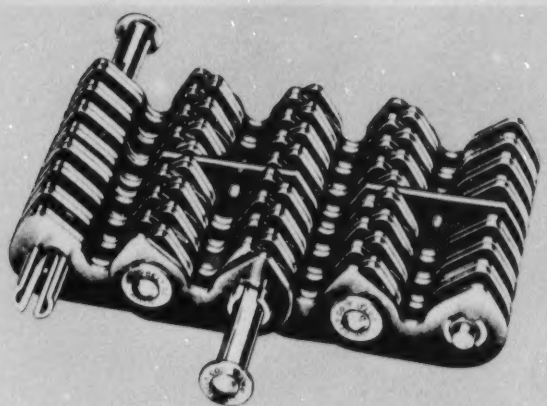
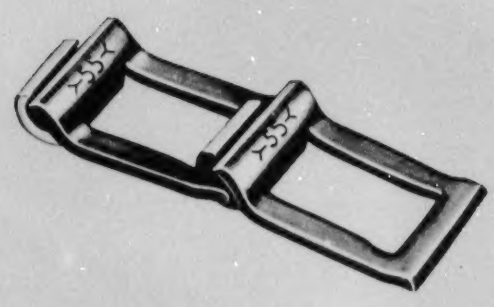
ROLLER CHAIN



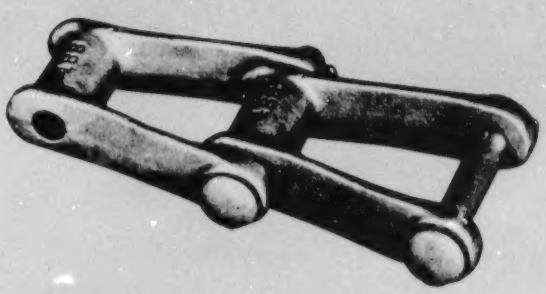
ROLLERLESS CHAIN



SILENT CHAIN



DETACHABLE LINK CHAIN



PINTLE CHAIN

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BLOCK CHAIN

Fig. 5 — Types Of Chains 34

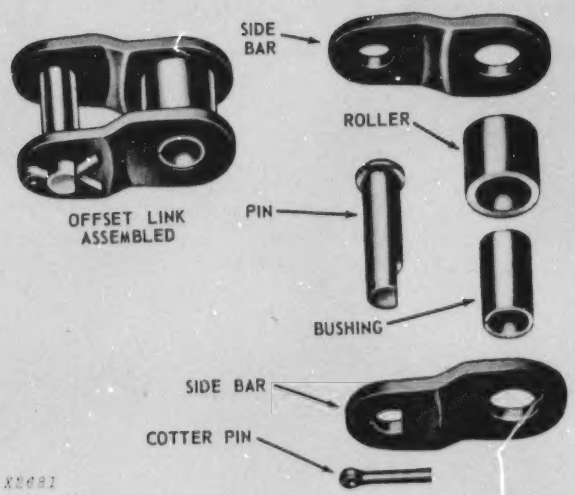


Fig. 6 — Roller Chain With Offset Links

Some roller chains have *offset* links, which are roller links and pin links combined (Fig. 6). The offset link is often used to connect chains where an odd number of links are required. However, offset links wear faster than straight links and so are avoided where possible.

Roller chains are available in double, triple, and other multiple strands as shown in Fig. 7.

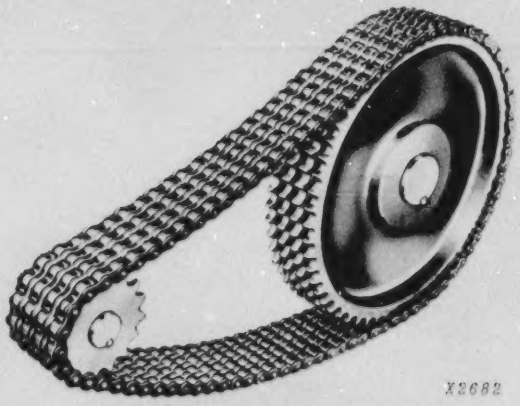


Fig. 7 — Roller Chain With Multiple Strands

Operation

As the roller chain goes around the sprocket, it bends or hinges at each link end. The sleeve turns on the pin, while the roller contacts the sprocket teeth and guides the link into place, absorbing most of the friction by a rolling motion.

Roller Chain Pitch, Width, And Roller Diameters

The *pitch* of a roller chain is the distance between the centers of the rollers (Fig. 8). Standard or *single* pitch is shown at the bottom, while extended

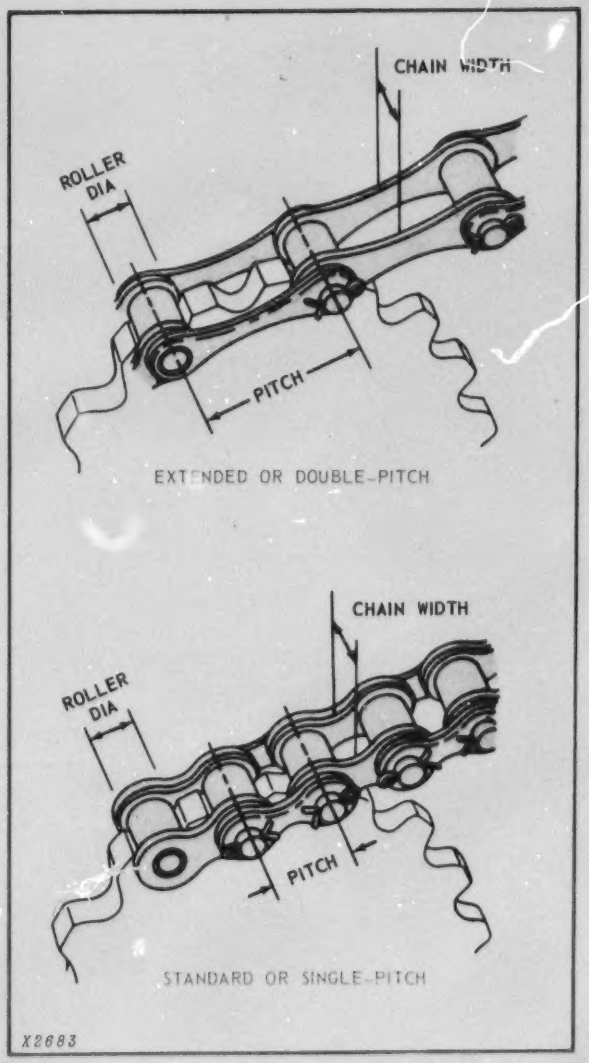


Fig. 8 — Roller Chain Pitch, Width, and Roller Diameters

or *double* pitch is shown at the top. As we said earlier, double pitch chains are cheaper but should only be used for light loads transmitted at low speeds.

Chain *width* is the distance between the inside edges of the side bars.

Roller *diameter* is the width across each roller in the chain.

Roller chains are numbered 40, 50, 60 etc. to match their sizes. The chart on the next page shows the standard chain numbers and what they mean in terms of pitch, width, and roller diameter.

Standard Roller Chain Sizes (New Chains)

Chain No.	150 Chain No.	Pitch Inches (mm)	Width (Inches)	Roller Diameter (Inches)
40	08A	½ (12.7)	5/16 (7.9)	5/16 (7.9)
50	10A	5/8 (15.8)	3/8 (9.5)	.400 (10.1)
60	12A	3/4 (19)	½ (12.7)	15/32 (11.9)
80	16A	1 (25.4)	5/8 (15.8)	5/8 (15.8)
100	20A	1¼ (31.7)	3/4 (19)	3/4 (19)
120	24A	1½ (38.1)	1 (25.4)	7/8 (22.2)
140	28A	1¾ (44.4)	1 (25.4)	1 (25.4)
160	32A	2 (50.8)	1¼ (31.7)	1⅛ (28.5)
180	*	2¼ (57.1)	1 13/32 (35.7)	1 13/32 (35.7)
200	40A	2½ (63.5)	1½ (38.1)	1 9/16 (39.6)

*No. 150 Number

ROLLERLESS CHAIN

Rollerless chain is used for lower speeds and where chain wear is not critical. A series of one-piece cast links are fastened with sidebars and pins (see Fig. 4).

In operation, the chain links contact the sprocket teeth and hinge to follow the circle of the sprocket. However, there is no rolling action in the chain; the only motion is the hinging which takes place inside the cast bushing or barrel of the link.

SILENT CHAIN

Silent chain is designed for quiet operation. It will run at high speeds — over 4500 feet per minute (1370 meters per minute) — with little noise or vibration. This chain is often used for valve timing in automotive engines.

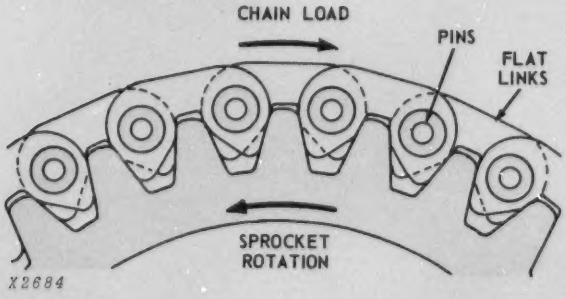


Fig. 9 — How A Silent Chain Engages The Sprocket

Silent chain is a series of flat metal links with a tooth shape at each end, connected by pins to form a flexible, continuous chain (Fig. 9).

The sprockets are similar to gears in appearance and design. The chain passes over the face of the sprocket like a belt and the teeth of the sprocket do not project through the chain (Fig. 9). This causes the links to enter and leave the sprocket in a smooth, orderly way.

The chain links are small in proportion to the chain's strength so it can be used on smaller sprockets. Some silent chains are made with links having teeth on both sides so that over-and-under serpentine drives can be used.

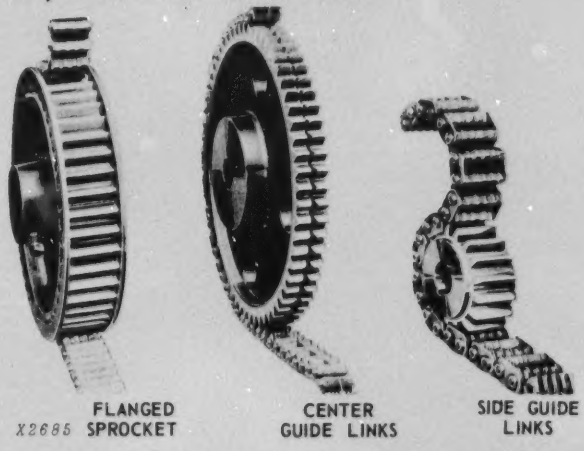


Fig. 10 — Three Ways Of Retaining Silent Chains

Silent chains can be retained on their sprockets in any of the three ways shown in Fig. 10.

DETACHABLE LINK CHAIN

This is a simple, cheap chain for slow speeds and very light loads. It is sometimes called "plain chain."

The links are of steel or cast-iron and are easily replaced. One end of the link is the hook end and the other the bar end.

Most chains can be driven in either direction, but detachable link chains are an exception (see Fig. 16).

PINTLE CHAIN

Pintle chain is used for slow speeds where abrasive materials and exposure to weather are critical. Link pitches from 1½ to 6 inches (38 to 150 mm) allow it to be used on a variety of conveyors. Speeds are usually 450 rpm or less, while loads are fairly light.

The chain is made up of a series of malleable iron links joined together by pins (see Fig. 4). The connecting pins are locked into the open end of the link and will not turn. As the chain forms around the sprocket, it hinges in the barrel, rotating around its fixed pin.

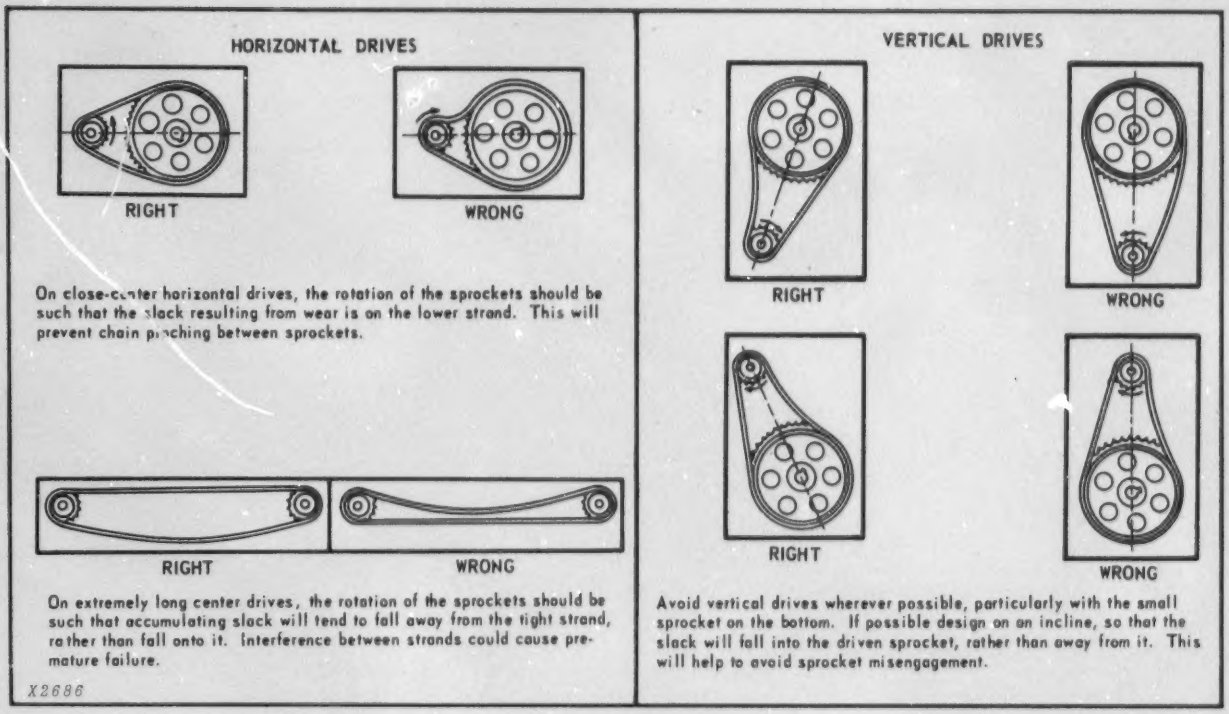

HORIZONTAL DRIVES
RIGHT
WRONG
On close-center horizontal drives, the rotation of the sprockets should be such that the slack resulting from wear is on the lower strand. This will prevent chain pinching between sprockets.
RIGHT
WRONG
On extremely long center drives, the rotation of the sprockets should be such that accumulating slack will tend to fall away from the tight strand, rather than fall onto it. Interference between strands could cause premature failure.
X2686
VERTICAL DRIVES
RIGHT
WRONG
RIGHT
WRONG
Avoid vertical drives wherever possible, particularly with the small sprocket on the bottom. If possible design on an incline, so that the slack will fall into the driven sprocket, rather than away from it. This will help to avoid sprocket misengagement.

Fig. 11 — Drive Arrangements

BLOCK CHAIN

This chain is a series of cast blocks joined by side bars and pins (Fig. 4). It is used for conveying small materials and may be equipped with pusher bars.

The chain is constructed by coupling two links with coupling pins or rivets which are securely locked against turning in the outside link. The coupling pins or rivets are free to turn in the smooth hardened bores of the bushings.

As the chain forms around the sprocket, hinging action takes place inside the bushing.

OTHER CHAINS

Here are some other chains which are less common:

1. **Bushing Chains** — all-steel chain for rugged conveying jobs. Made up of alternate straight side bar **inner** links and straight bar **outer** links. The inner link is made of two side bars and two hardened steel barrels or bushings.

2. **Straight Sidebar Chain** — a simpler version of the bushing chain, using only two side bars and with rollers at the link pins.

3. **Leaf Chain** — tension links for lifting and counterbalancing chains; very high-strength.

4. **Side Bow Chain** — a standard roller chain with special pin links which allow side flexing for curved or twisting conveyor lines.

5. **Plate Top Chain** — large plates for conveying are fastened to tops of roller links. (Larger version is used as tracks on crawler tractors.)

6. **Flexible Chain** — This chain replaces belts in some applications. The metal slats form teeth as they operate. Variable-speed drive (see "Belts") is also an option with this chain.

7. **Saw Chain** — This is a special chain for cutting wood.

DRIVE ARRANGEMENTS

The relative position of sprockets in chain drives is carefully planned to get maximum life from the drive. Various arrangements are illustrated in Fig. 11. Direction of rotation is shown by the arrows.

LOCATION OF CHAIN TIGHTENERS

On drives where it is not practical to have adjustable centers, or where longer center distances might cause the slack side of the chain to strike an obstruction or "whip" too much, the installation of a chain tightener is recommended. The sketches in Fig. 12 illustrate the proper locations for most efficient operation.

CONVEYOR AND ELEVATOR CHAIN TIGHTENERS

Most conveyors and elevators require control of chain tension through the use of a tightening device (Fig. 13).

Adjusting to the proper chain tension can often correct such conveyor problems as surging and buckling. With proper tension, the wear on chain and sprockets resulting from improper tooth engagement and from lateral trailing of the chain can be drastically reduced. Tighteners are also useful for equalizing the tension in two or more strands of chain applied to a single conveyor system.

Proper conveyor and elevator chain tension should:

1. *Allow for chain elongation caused by both chain wear (progressive) and elastic stretch (intermittent).*

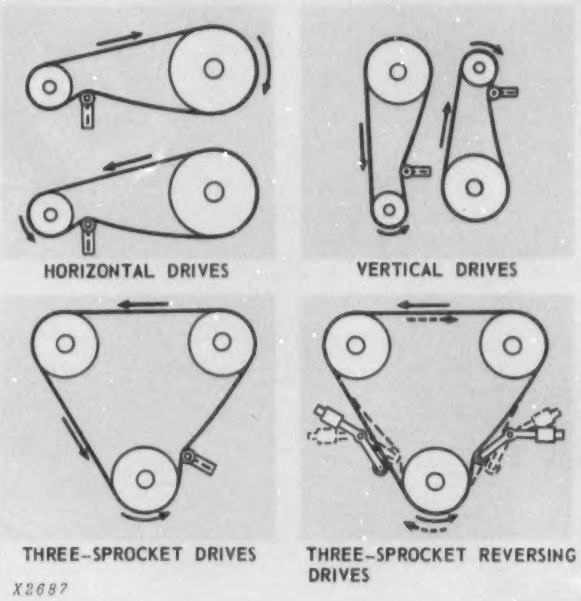


Fig. 12 — Location Of Chain Tighteners

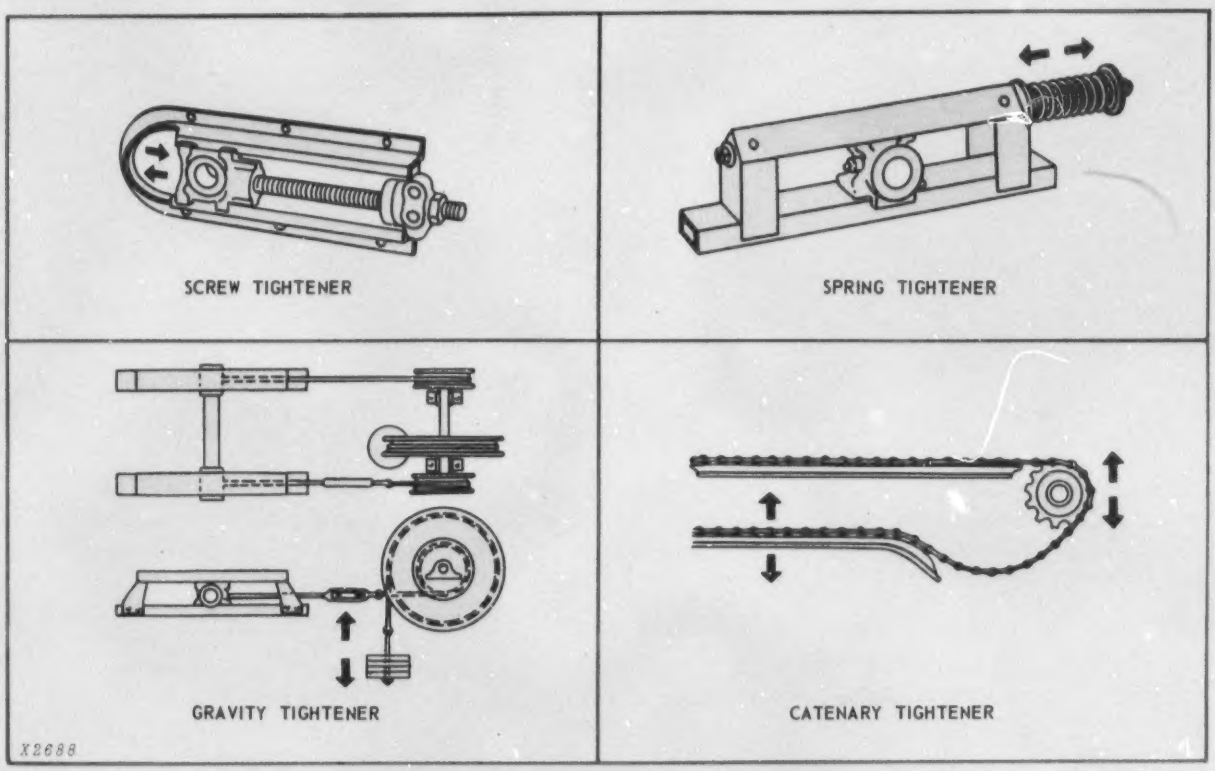


Fig. 13 — Chain Tighteners For Conveyors And Elevators

2. *Be based on operating or running conditions (not static conditions).*

3. *Avoid any static overloading.*

4. *Provide temporary chain slack for coupling and maintenance.*

5. *Use a positive tightening system.*

6. *Involve frequent inspection and resetting of take-ups.*

Tightening devices can be either manual, such as the screw type, or automatic, such as the gravity type or spring type (Fig. 13). Some applications may require both.

Following are typical tightening devices:

Screw Tightener

Used where periodic manual adjustments are sufficient.

Gravity Tightener

Used where constant adjustment is desirable to compensate for chain wear.

Spring Tightener

Especially useful for shock loading conditions. Because of limited travel of the spring, manual adjustments are also necessary.

Catenary Tightener

Useful in long conveyors where the catenary can follow the drive sprocket, relieving chain tension throughout the rest of the conveyor. The catenary provides "automatic" tensioning of the chain.

MATCHING CHAINS AND SPROCKETS

Replacement chains will operate on the same sprocket only if these three dimensions are the same:

1. *Chain pitch*

2. *Roller or bushing diameter*

3. *Inside chain width*

The three dimensions above are shown in Fig. 8.

When replacing chains, all three dimensions must match. Otherwise, the sprockets must also be replaced.

Be careful when assembling parts from another chain into one already in use. Poor fits can shorten chain life. Normally, this is done only in an emergency — then only until normal repairs can be made.

When two or more chains operate side by side, the total assembled chain pitch must be the same. If not, the shorter strand will be overloaded, or the chain can become twisted when engaging the sprockets. To avoid trouble, replace multiple strands as a complete unit.

"HUNTING TOOTH" SPROCKET DESIGN (DOUBLE-PITCH CHAINS)

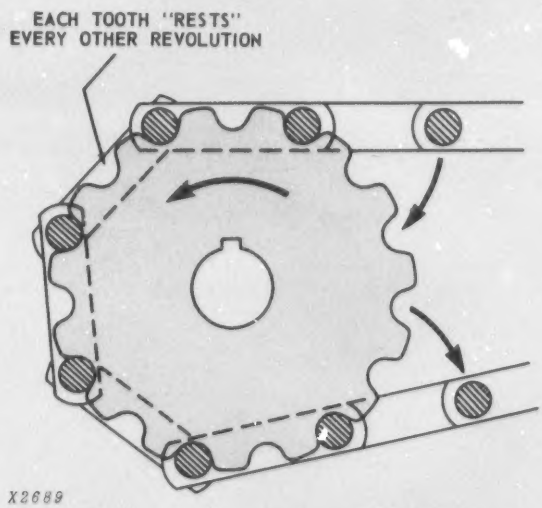


Fig. 14 — "Hunting Tooth" Sprocket Design (Double-Pitch Chains)

The rate of wear in sprocket teeth can be retarded by the use of double-cut sprockets with the "hunting tooth" design (Fig. 14).

This arrangement provides an "extra set" of teeth, as well as an odd number of teeth, so that *each tooth contacts the chain only every other revolution.* Less contact results in proportionately less wear.

Obviously, this can only be used with double-pitch chains. The space available for the extra set of teeth must be adequate to provide tooth sections of proper strength.

RELATIVE SPEED OF SPROCKETS

Relative speed of sprockets is the same as for belt pulleys or sheaves.

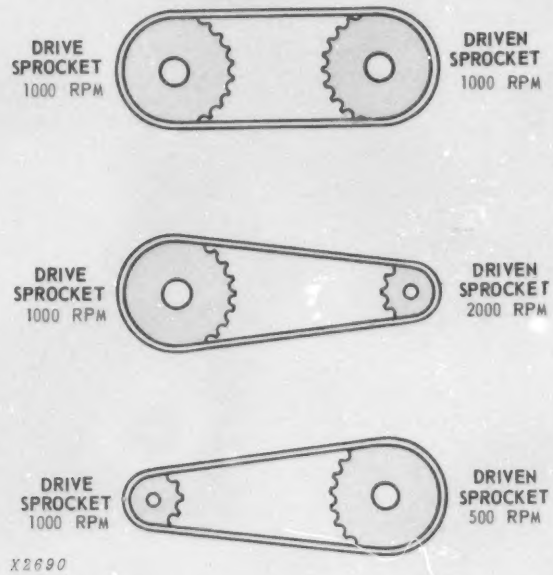


Fig. 15 — Relative Speed Of Sprockets

When two sprockets are the same size, they will rotate at the same speed (Fig. 15).
If we keep the same *drive* sprocket, but use a smaller *driven* sprocket, the driven shaft will turn faster as shown.

If we use a smaller *drive* sprocket, but keep the *driven* sprocket the same, the driven shaft will turn slower.

PROPER DIRECTION OF CHAIN TRAVEL

Chains must be operated in the proper direction to assure maximum wear life of both chain and sprockets. Follow the recommendations below to reduce wear on pin bearing surfaces, chain links, and sprocket teeth.

1. **Standard Roller Chains and Double-Pitch Roller Chains,** with straight side links, travel in *either* direction (Fig. 16, top).

2. **Detachable Link Chains** travel with hook ends forward and slots outward as shown. Otherwise, the bars wear excessively.

3. **Pintle and H-Type Chains** should be operated with the barrel forward.

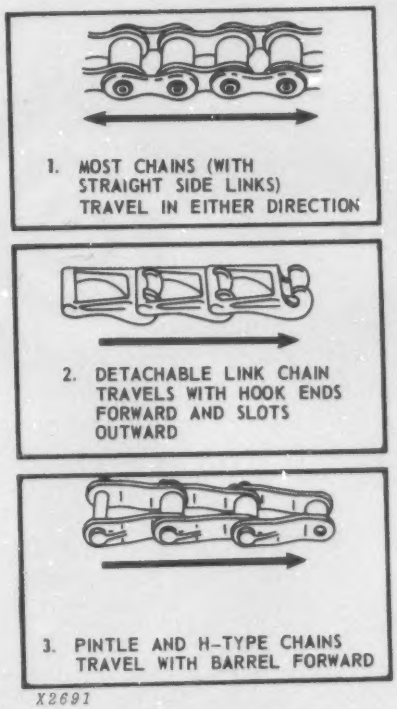

1. MOST CHAINS (WITH STRAIGHT SIDE LINKS) TRAVEL IN EITHER DIRECTION
2. DETACHABLE LINK CHAIN TRAVELS WITH HOOK ENDS FORWARD AND SLOTS OUTWARD
3. PINTLE AND H-TYPE CHAINS TRAVEL WITH BARREL FORWARD
X2691

Fig. 16 — Proper Direction Of Chain Travel

Only for special speed-up or long center drives, should the chains in (2) and (3) above be operated with the open end forward.

STARTING AND STOPPING CHAINS

In general, avoid starting a chain which is under heavy load. Engage the chain drive SLOWLY and check for proper operation before putting it under full load.

CONVEYOR AND ELEVATOR CHAINS

These chains require special precautions for starting and stopping.
To avoid overloads, follow these steps:

1. Whenever possible, unload a conveyor or elevator before shutting it down. This allows a re-start under no load and prevents a down-load from standing on the conveyor during shutdown.

2. Before start-up, check the surrounding area for obstructions that might overload the chain. Also before starting, or preferably after stopping, clean out any foreign material, especially the kind that "sets up" or hardens. Whenever possible, clean an elevator before starting it.

3. Start the chain and run it for a moment before applying a load. Check lubrication, and be sure all chain joints articulate freely.

4. Run chains periodically during shutdown periods to keep joints from binding or "freezing" and to reduce overloads when starting.

5. If the chain runs in excessive heat, start it before the temperature is elevated. When stopping, run until heat has lowered to the normal range for a stationary chain.

CAUTION: Keep hands, feet, and clothing away from chain drives while in operation.

ALIGNING SHAFTS AND SPROCKETS

Proper alignment of sprockets and shafts is necessary for maximum wear life. Rapid wear will result from misalignment due to rubbing of chain parts against sides of sprocket teeth and excessive friction wear in the joints caused by racking and twisting of chains.

To assure correct alignment, follow these steps:

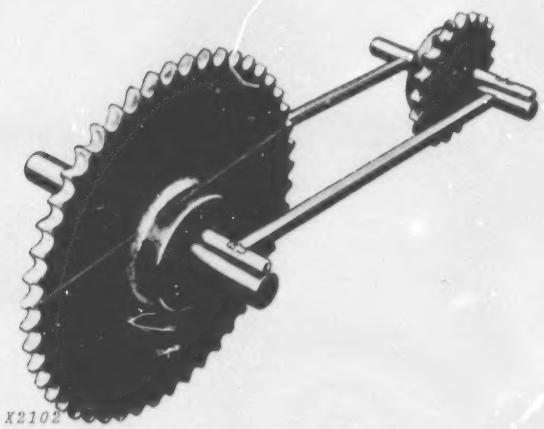


Fig. 17 — Leveling Shafts Using A Machinist's Level

1. Carefully **level the shafts** if they are running on the same line. Use a machinist's level directly on the shafts (Fig. 17). With a multiple-width sprocket, a spirit level can be applied across the sprocket teeth.

2. **Align the shafts**, using a feeler bar to see if they are parallel (Fig. 18). Recheck the level adjustment. Tighten all securing bolts and nuts to hold alignment.

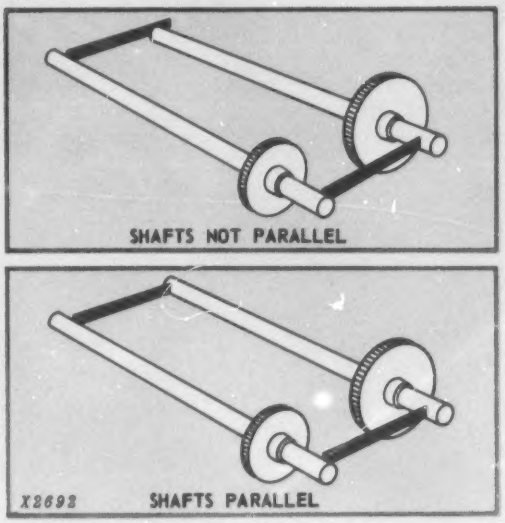


Fig. 18 — Aligning Shafts For Parallelism Using A Feeler Bar

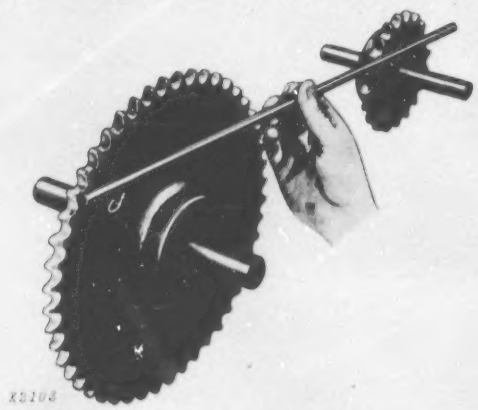


Fig. 19 — Aligning Sprockets Using A Straight Edge

3. **Align the sprockets** axially on the shafts, using a straight edge (Fig. 19). Take care to apply the straight edge to a finished surface on the side of the sprocket. For long center distances, a stretched wire can be used instead of a straight edge.

4. With a shaft having some endplay (as the shaft of an electric motor), *align the sprockets with the shaft in its running position.* To determine the running position, chalk the shaft, run the motor at operating speed, and scribe a line in the chalk opposite a convenient fixed point. Adjust the alignment with the shaft blocked in this position.

5. *Secure each sprocket* against axial endplay by means of a setscrew, or by collars setscrewed to the shaft. However, do not depend on setscrews to prevent the sprockets from turning on the shaft . . . keyways in the shaft are best.

INSTALLING AND DETACHING CHAINS

To couple the ends of a chain:

1. Loosen the tighteners to provide sufficient "working slack".

2. Bring the ends together over one sprocket, using the teeth to hold the chain.

Fig. 20 — Installing Roller Chain

3. Insert pin or pin link to couple chain into an endless strand (Fig. 20).

4. Adjust tighteners to provide proper tension for operation.

The above method is especially useful for coupling drive chains.

When it is necessary to couple chain in the span between sprockets, draw the ends together with a block and tackle or other device. Then follow steps 3 and 4 above.

Keep chain straight when coupling. A link coupled when the chain is crooked may cause the chain to twist in operation.

To provide a solid back-up for the chain, assemble it in a straight line on the floor or a table as illustrated at top in Fig. 21. Then feed the chain onto its drive.

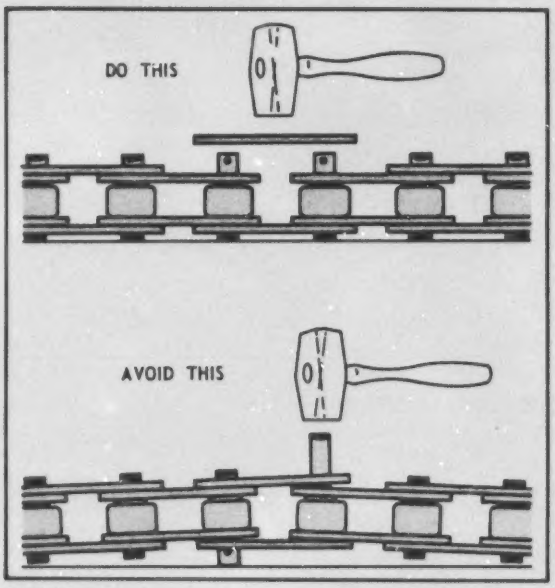


Fig. 21 — Coupling Chains

For straight sidebar chains, avoid driving the pin all the way through from one side (Fig. 21, bottom). Instead, assemble both pins in one sidebar, insert in the chain, and then assemble the second sidebar from the other side (Fig. 21, top).

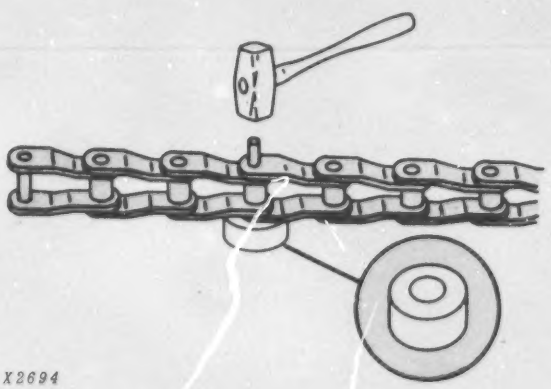


Fig. 22 — Coupling Offset Sidebar Chains

When coupling offset sidebar chains, support the lower sidebar around the pitch hole with a block having a hole large enough to accommodate the pin end (Fig. 22). This will also prevent bending the sidebars.

In most chains there is a press fit between the pins and the sidebar holes. To preserve this fit, couple and uncouple the chain as little as possible.

Do not weld pins in sidebars. Instead, cotter or rivet the pin ends. In most cases, the press fit alone is sufficient to hold the pin in the sidebar. If possible, use a straight coupler link rather than an offset one.

CAUTION: Keep all chain guards and shields in place during operation.

Chain Detaching Tools For Roller Chains

The chain detacher is an inexpensive, convenient bench tool for uncoupling precision roller chain. It is designed to prevent damage to the chain during disassembly.

The chain detacher in Fig. 23 (bottom) consists of two pieces; a fork and an anvil block. The fork is slotted to fit the chain pitch and roller diameter and has tines of ample width to support the roller link sidebars. The block and fork hold the chain in proper position, allowing the pins to be driven squarely out of the sidebar.

In another type of chain detacher (Fig. 23, top), the chain is clamped into the fixture while a plunger is used to push the pin out.

Detachers are made for all popular sizes of roller chain and are readily available.

The best rule when detaching any chain is: *Support the chain while detaching it.*

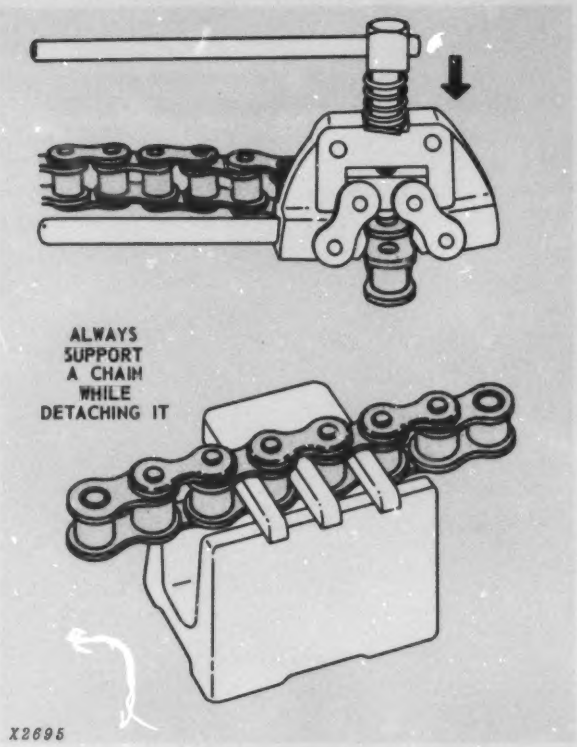


Fig. 23 — Chain Detaching Tools For Roller Chain

Installing or Removing Detachable-Link Chains

To detach without a tool, bend the chain as shown in Fig. 24 (left) and strike the side of the link to drive it out. The hook opening is slightly smaller than the side bar so a light hammer blow is needed to uncouple the links.

Couple the chain again in the same way. Be sure that the chain points in the direction shown by the arrow in Fig. 16, center.

To detach using a tool (Fig. 24, right), place the chain in the slot as shown and strike the side of the link with a hammer.

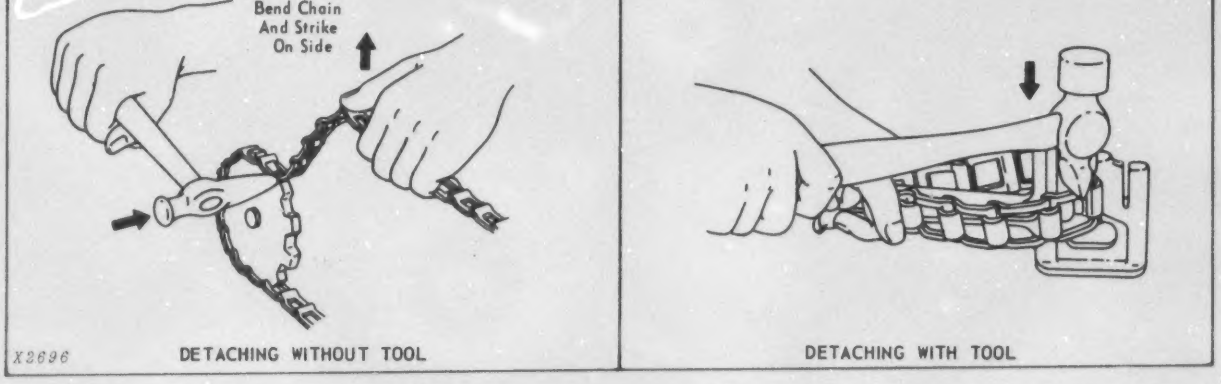


Fig. 24 — Removing And Installing Detachable-Link Chain

FOS — 53 Litho in U.S.A.

Installing Conveyor Or Elevator Chains

Because of their length and weight, conveyor and elevator chains require special handling.

These chains are normally shipped coiled in segments. For elevators using a single strand of chain, couple the chain segments together and bolt the buckets to the attachments with the chain stretched out. This simplifies handling and installation and also helps to keep the chain straight. Crooked or twisted chain can cause operating difficulties.

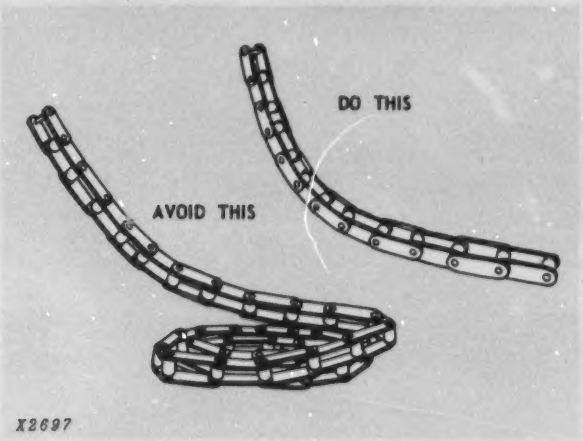


Fig. 25 — Feeding Chain Onto Conveyors Or Elevators

Do not feed the chain in on its side. Prevent the possibility of twist by feeding it in as shown in Fig. 25.

If the chain is twisted, straighten it by giving it a careful reverse twist with crowbars. Do this only while the chain is stretched out on the floor.

The quickest and easiest method for installing a vertical elevator chain is to lower it down over the head sprocket as shown at left in Fig. 26. The chain ends are then coupled together at one of the lower casing openings. Adequate overhead space and hoisting equipment must be available for this method of installation.

A more common method, shown at right in Fig. 26, is to feed the chain through one of the lower casing openings, hoisting it in place one end at a time. This is done by hooking the chain several links back from one end. Slowly hoist the chain and place the short "free" end over the head sprocket. Secure the chain to prevent movement. Now hook the other end of the chain and hoist it into position as shown. Couple the two ends together at the head sprocket.

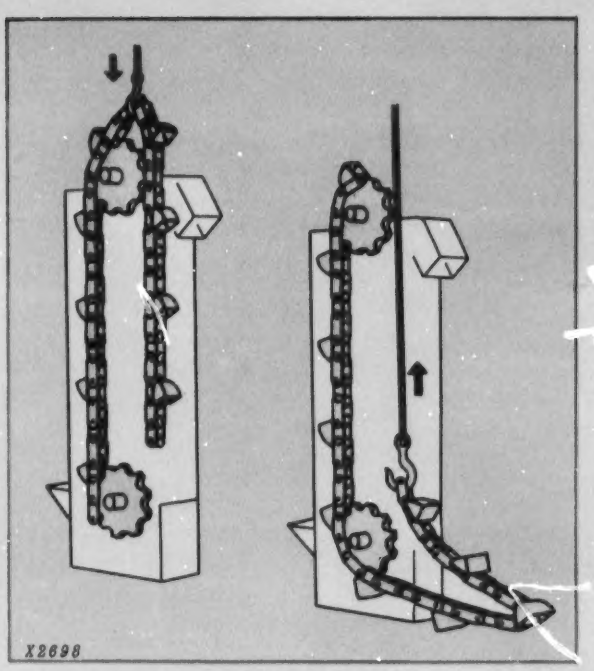


Fig. 26 — Installing Chain On Vertical Conveyors Or Elevators

When replacing an elevator chain, uncouple the worn chain at the lower sprocket and attach the new chain. Thread the new chain into the elevator casing by carefully "jogging" the elevator drive or by pulling on the loose end of the old chain.

CHAIN SLACK

The correct amount of slack is essential to the proper operation of chain. Unlike belts, chain requires no initial tension and should **not** be tightened around the sprockets. Properly adjusted chain drives should permit slight flexing by hand in the slack strand of about 2 percent of the center distance (Fig. 27).

Chains Too Tight

When chain is *too tight*, the working parts carry a much heavier load than is necessary and work much harder without delivering any more power than properly installed chain. This causes rapid chain wear because of increased pressures in the joints. In addition, this overloads and accelerates wear in the shaft bearings.

Chains Too Loose

Too much slack is also harmful. On long centers, particularly, too much slack will cause vibration and chain whipping, reducing the life of the chain.

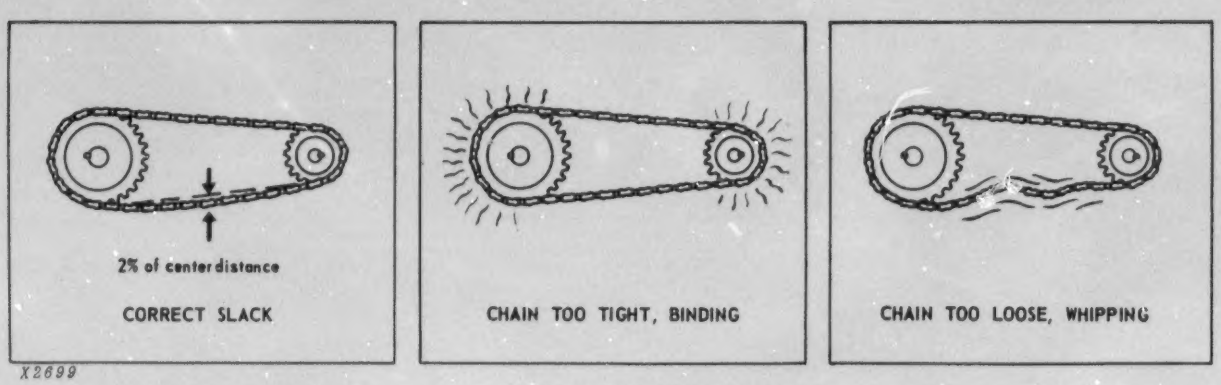


Fig. 27 — Chain Slack

On long centers, the slack strand should be supported or taken up by idler sprockets or guides. The strip is simply a continuous support for the chain which prevents it from sagging too much.

How Chains "Stretch"

The "stretch" a chain develops in service is due to material being worn off the pin and bushing bearing surfaces. After a period of operation, slack must be taken up to prevent the chain from jumping the sprockets.

All chain joint wear occurs when the chain is flexed over sprockets under load.

A chain adjusted with the proper amount of slack flexes only twice under load during each trip around the loop — once as the joint comes off the *driven* sprocket and again as it enters the *drive* sprocket.

When a chain is adjusted "fiddle string tight," wear is accelerated because each joint flexes four times under load as it travels around the chain loop.

How To Adjust Chains

For horizontal and inclined drives, the chain sag should be about ¼ inch per foot (10.5 mm per half meter) between shaft centers (with one side of chain taut).

Vertical drives and those subject to shock loading or reversal of rotation should be adjusted so that both spans of chain are almost taut.

For drives on fixed centers, chain tension is usually controlled by an adjustable chain tightener, either an idler sprocket or a shoe.

To determine the amount of sag, pull one side of the chain taut, allowing all the excess chain to accumulate in the opposite span.

Place a straight edge over the slack span and pull the chain down at the center (Fig. 28). Measure the amount of sag from the top of the chain to the underside of the straight edge.

If necessary, adjust the shaft centers or the tightener to provide the recommended amount of sag for proper chain slack.

NOTE: On many sprockets — particularly cast ones — the teeth may not be perfectly concentric with the shaft. For this reason, be sure to turn the drive several times to recheck slack in all positions of the sprockets.

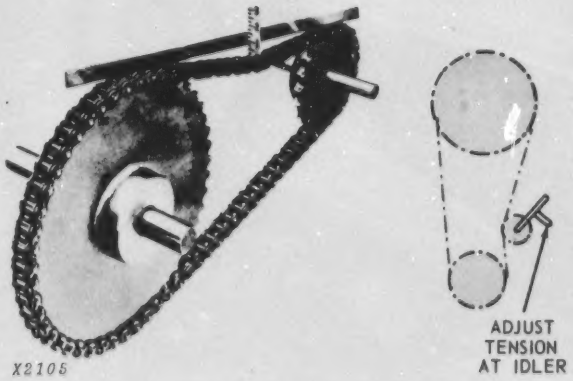


Fig. 28 — Adjusting Chains

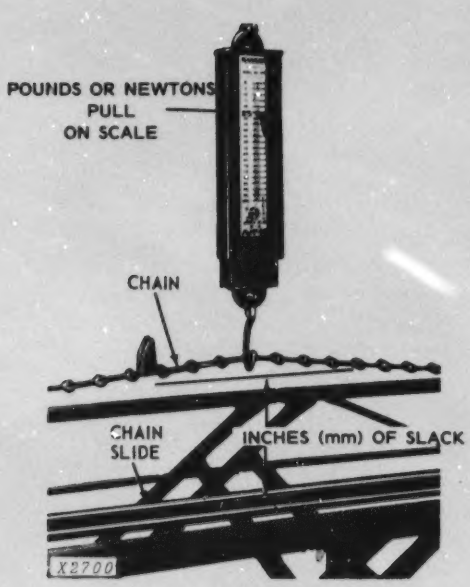


Fig. 29 — Checking Slack On Long Conveyor Or Elevator Chains

On long chains for conveyors and elevators, slack is usually checked by pulling on the chain at the center of one side with a spring scale and measuring the slack at a recommended pounds pull (Fig. 29).

Some long chains use automatic tighteners and do not require adjustment.

CAUTION: Never attempt to adjust chains while they are operating.

ROLLER CHAIN "DON'TS"

- *Never insert a new link in a chain that's been lengthened greatly by wear. The "bite" of the new link will be different and the resulting shock, each time the link engages the sprocket, will soon destroy the chain.*
- *Don't install a new chain on badly worn sprockets. A few hours' operation under such conditions will do more damage to the chain than years of normal use.*
- *Don't run chains too tight or too loose. Tight chains cause excessive loads on bearings. Loose chains cause noisy operation, chain pulsations or whipping and result in irregular sprocket speeds and abnormal wear.*
- *When installing a link, don't drive the connecting link plate down too far on the pins. This "squeezes" the chain joint so no oil can get down in between the link plates, keeps joints from flexing and results in "whipping."*

CLEANING CHAINS

Periodic cleaning is good economy under even the best operating conditions. Follow these steps:

1. *Remove chain from sprockets.*
2. *Wash chain in diesel fuel.*
3. *Drain diesel fuel and soak chain in oil.*
4. *Hang chain to drain off excess lubricant.*
5. *Install chain.*

STORING CHAINS

Storing New Chains

Keep new chain in its box or wrapping. Store it indoors in a protected location, to keep grit and dirt out of the joints, and away from excessive heat or moisture, which destroys the initial factory lubrication.

Storing Chains On Idle Equipment

If equipment is to be idle for any length of time, protect chains from deterioration and prolong life as follows:

1. Clean thoroughly, removing chain if possible.
2. Cover chain with heavy grease.
3. Wrap unmounted chain in heavy paper and store inside.
4. Apply a coating of grease to all finished surfaces of sprockets, and to any chain left mounted.

NOTE: When placing equipment back into service, clean chains and sprockets and relubricate thoroughly. Gummy storage lubricants cause excessive wear on chains and sprockets, and prevent entry of fresh lubricant into the joints later on.

Chains on elevators or conveyors which cannot easily be removed should be periodically run to prevent joints from "freezing" or binding and to reduce overloads when starting.

LUBRICATING CHAINS

There are four vital reasons for lubricating chains:

- **Reduce wear**
- **Protect against rust, corrosion, and heat**
- **Prevent seizing of pins and bushings**
- **Cushion shock loads**

Lubrication of chains is perhaps the most important factor in long service life. Running dry, exposed chains have been known to wear out in less than 200 hours. Manual lubrication can extend wear life three to ten times over life with no lubrication.

Dripping oil on the outside of the chain may not be enough. Oil must reach the vital bearing surfaces pointed out in Fig. 30, top. To do this, oil must penetrate the gap between the inside and outside plates of roller chains. This can be helped by oiling the chain while it is warm and then running it for a short time.

Chains which collect dirt and dust should still be oiled regularly. A "paste" of oil and dirt still wears less than dry dirt packed into the chain joints.

NOTE: For certain abrasive soil or sandy conditions, some manufacturers may not recommend lubrication of chains. However, this is the exception, not the rule.

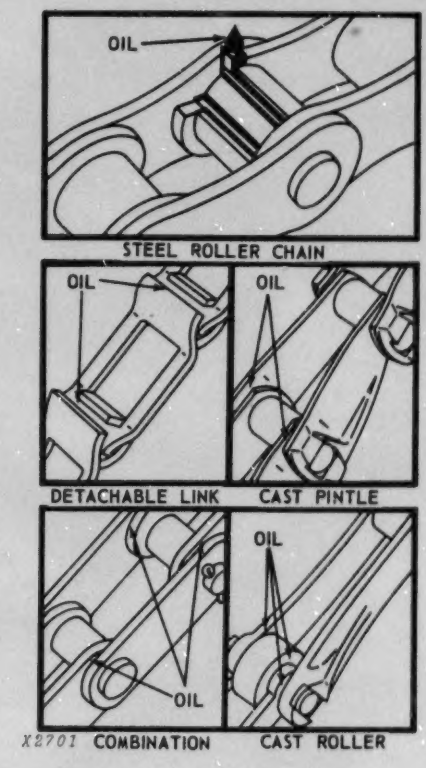


Fig. 30 — Lubrication Points On Chains

The methods of lubricating chain drives are explained in the chart in Fig. 31 below.

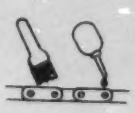
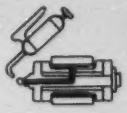
METHOD OF LUBRICATION	MANUAL		SEMI-AUTOMATIC	AUTOMATIC		
APPLICATION OF LUBRICANT	Brush or oil can	Pressure lubrication	Drip Cup	Oil Bath	Oil Disk	Oil Stream
			Contact brush, direct dip	Chain dips into oil	Oil disk throws lube up on chain	Pump sprays oil on chain
						
KIND OF EQUIPMENT	Conveyors, Elevators, Simple Drives	Conveyors	Conveyors and Elevators. Drives in low horsepower and speed range	Drives—low to moderate horsepower and speed	Drives—moderate to high horsepower and speed	Drives—high horsepower and speed

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Fig. 31 — Methods Of Lubricating Chain Drives

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METHODS OF LUBRICATING CHAINS

Methods of lubricating chains are:

1. **Manual**
   - *a. Oil can*
   - *b. Brush*
   - *c. Pressure (grease gun)*
2. **Semi-Automatic**
   - *a. Drip cup*
3. **Automatic**
   - *a. Oil bath*
   - *b. Oil disk*
   - *c. Oil stream*

Notice that manual lubrication is adequate for most conveyors, elevators, and simple drives, while more complex drives with higher speeds and loads require more lubrication — some constantly by automatic devices.

Here are some lubrication tips for the various methods:

Manual lubrication: Make sure that the lubrication schedule is being followed and that oil is being properly applied. (Usually with a brush or spray can just before the chain goes around a sprocket — apply every eight hours).

CAUTION: Use the necessary safety precautions when lubricating chains.

Drip lubrication: Inspect the filling of oiler cups and the rate of feed. Check that the feed pipes are not clogged.

Oil Bath or Disk systems: Inspect the oil level and check that there is no sludge.

Oil Stream systems: Inspect the oil level in the reservoir, check the pump drive and the delivery pressure so that there is no clogging of the piping or nozzles.

With reservoir systems, drain and refill at least once a year.

In general, oil viscosities should be the same as for machine engines: Use heavier oils in hotter weather and lighter oils in colder weather.

Remember these six points about chain lubrication:

1. Lubricate at regular intervals — even when chain collects dirt or dust.

2. At higher speeds, lubricate more frequently.

3. Remove excess dirt and dust from chains before lubricating.

4. Lubricant must penetrate the chain joints.

5. Protect the chain from contaminants wherever possible.

6. Follow manufacturer's instructions on lubrication.

CHAIN WEAR

Single-pitch chains should be replaced when wear elongation (stretch) equals 3 percent of the original chain length.

For example, a 66-pitch strand of ¾-inch-pitch (19-mm-pitch) roller chain has an original length, when new, of 49½ inches (1257 mm). When the chain elongates to 51 inches (1295 mm), it is ready for replacement.

When wear elongation reaches 3 percent, the file-hard bearing surface on pins and bushings has worn away, and joint wear greatly accelerates, requiring frequent slack adjustment.

Single-pitch chain can be operated past the 3 percent point, but the relatively few extra service hours obtained will not compensate for the down-time required for frequent slack adjustment.

Many low-speed, lightly loaded drives use double-pitch chain. Since double-pitch chain has only half as many joints per foot (meter), the pin and bushing case are worn through when wear elongation reaches 1-½ percent of original chain length. Consequently, double-pitch chain is ready for replacement at 1½ percent stretch.

As chains wear and stretch, they do not mate properly with their sprocket teeth (Figs. 32 and 33). Badly worn roller chains ride so far out of the tooth pockets that they may be off the working faces (Fig. 32, right).

Worn silent chains ride higher in the sprocket teeth as they wear (Fig. 33, top).

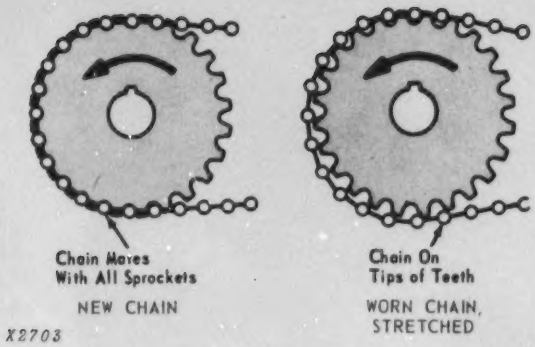

Fig. 32 — Comparing New And Worn Roller Chains

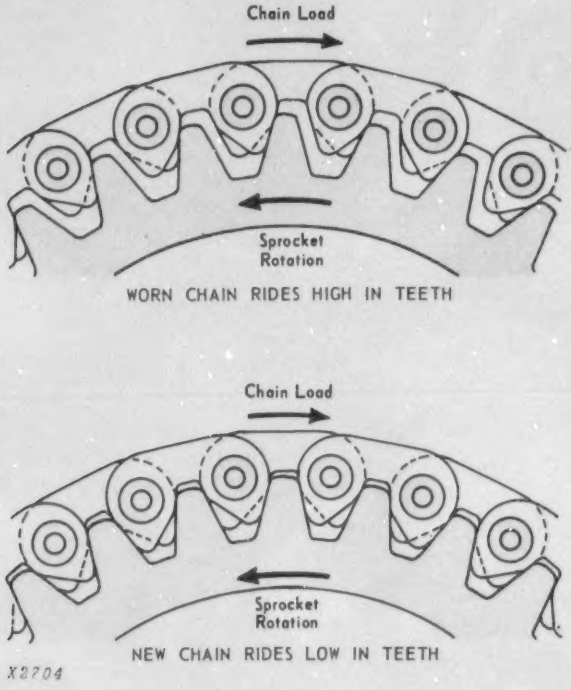

Fig. 33 — Comparing New And Worn Silent Chains

WEARING OF CHAIN PARTS

When chains are worn and do not fit their sprockets, the link entering the driven sprocket on the slack side will be on top of the sprocket tooth, and will jump a tooth, causing extremely high loads in the chain links. The abnormally high loads cause chain breakage and terminate the life of the drive.

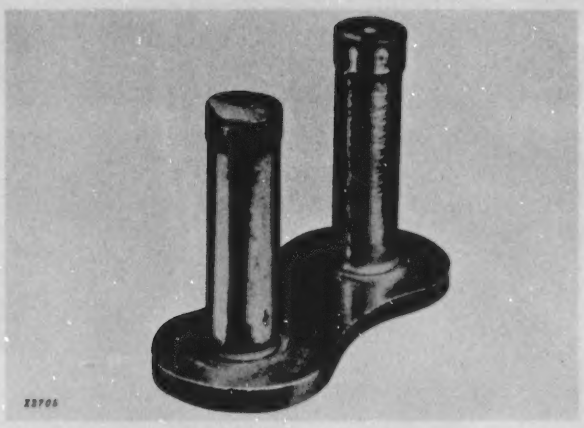

Fig. 34 — Pin Wear (Lack Of Lubrication)

The wear rate of a chain depends upon many factors, the most important of which is lubrication. Discolored pins (brown or black due to "burned oil") or red oxide (fretting) are sure signs that the chain joint has not received sufficient lubrication (Fig. 34). A chain wears many times faster when run dry than when run well lubricated. Because a little oil greatly reduces the wear rate, wear will vary widely in the same chains. Two chains being compared rarely have exactly the same amount of oil reaching the joints.

Starved lubrication also causes some joints in the chain strand to wear more rapidly than others which causes the chain to operate very roughly and makes it impossible to obtain the proper slack adjustment for the entire strand length.

Another factor known to influence chain joint wear is the "severity of environment." Abrasive material that can reach the chain joints will cause rapid wear. Even though chains operate in abrasives, lubrication can extend chain life. Corrosion also greatly accelerates pin and bushing wear.

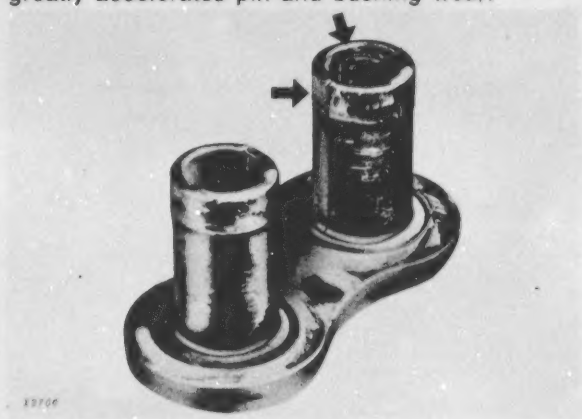

Fig. 35 — Bushing Wear (Note Wear On Both Inside And Outside Diameters)

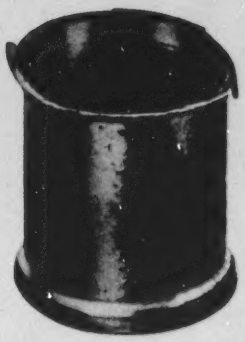

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Fig. 36 — Roller Wear

The drive itself also influences wear life of the chain. For example, in transmitting a given horsepower at a given rpm, the fewer the teeth in the sprocket, the greater the wear rate of the chain. Maintaining the correct amount of chain slack is also essential for obtaining maximum drive life. Finally, misaligned or worn sprockets are other factors that increase the wear rate of a chain drive.

Never insert new links in a chain that has been elongated by wear. The new links will have shorter pitches, causing shock when engaging the sprocket. This will soon destroy the chain.

Do not install a new chain on badly worn sprockets. More damage will occur to the chain in a few hours than under months of normal use.

GALLING

Galling of bearing surfaces occurs when the mating surfaces weld. When a chain joint galls and the joint flexes over the sprockets,the weld breaks and tears chunks of metal out of the surface of the pin and bushing (Fig. 37). When galling occurs, "wear" is extremely rapid.

Galling always occurs because of lack of lubrication in the chain joints. On well-lubricated chains with hardened pins and bushings, and operating within recommended speed limits, galling will not occur at loads up to yield strength of the chain. If chain speed is greater than the recommended, it is impossible to get lubrication into the chain joint, regardless of how much oil is put onto the chain. Under these conditions, galling will occur even though working chain tension is very low.

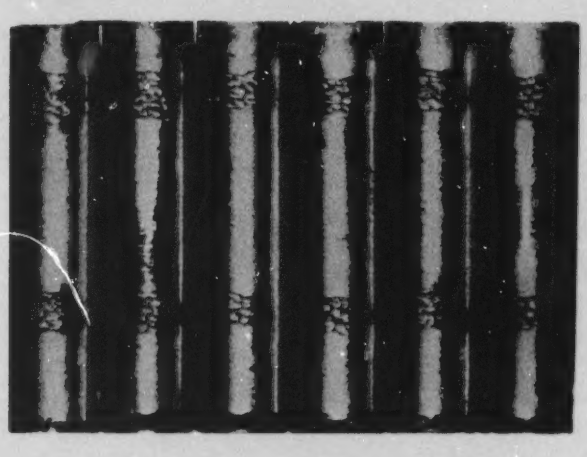

Fig. 37 — Galling Of Chain Pins

CHECKING WEAR ON CHAINS

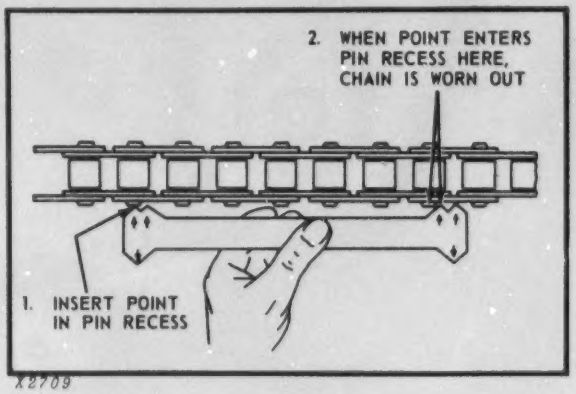

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Fig. 38 — Using Special Gauge To Check Wear On Roller Chain

Special gauges are available which check wear on chains. The gauge shown in Fig. 38 tells that the chain is worn out when both points will enter pin recesses.

WEAR LIMITS ON ROLLER CHAINS

The chart on the next page shows typical wear limits on single-pitch roller chains. When the chain wears and "stretches" until it reaches the "old" length, it should normally be replaced.

NOTE: To diagnose various kinds of chain failures, see "Trouble Shooting" at the end of this story.

WEAR LIMITS ON ROLLER CHAINS								
Strand Length In Pitches	**Chain Length In Inches (Millimeters)**							
	No. 40 Chain (08A)		*No. 50 Chain (10A)*		*No. 60 Chain (12A)*		*No. 80 Chain (16A)*	
	New	*Old (Replace)*	*New*	*Old (Replace)*	*New*	*Old (Replace)*	*New*	*Old (Replace)*
40P	20 (508)	20⅝ (523)	25 (635)	25¾ (654)	30 (762)	31 (787)	40 (1016)	41¼ (1047)
50P	25 (635)	25¾ (654)	31¼ (793)	32$^{9}/_{16}$ (817)	37½ (952)	38⅝ (981)	50 (1270)	51½ (1308)
60P	30 (762)	30⅞ (784)	37½ (952)	38⅝ (981)	45 (1143)	46⅜ (1177)	60 (1524)	61¾ (1568)
70P	35 (889)	36 (914)	43¾ (1111)	45$^{9}/_{16}$ (1144)	52½ (1333)	54 (1371)	70 (1778)	72 (1828)
80P	40 (1016)	41¼ (1047)	50 (1270)	51½ (1308)	60 (1524)	61¾ (1568)	80 (2032)	82½ (2095)
90P	45 (1143)	46⅜ (1177)	56¼ (1428)	58 (1473)	67½ (1714)	69½ (1765)	90 (2286)	92¾ (2355)
100P	50 (1270)	51½ (1308)	62½ (1587)	64⅜ (1635)	75 (1905)	77¼ (1962)	100 (2540)	103 (2616)

CHAINS BREAKING

1. Link breakage is usually due to fatigue and may be caused by the installation being underdesigned, excess vibration, the chain jumping the sprocket teeth resulting in severe and abnormal overloading, shafts out of parallel, or a foreign object entering between the chain and the sprocket tooth. A tensile breakage of the link may develop due to the same causes.

2. If tensile chain breakage does occur, it will usually be the pin. Such breakage generally develops due to overloading caused by the chain or sprocket becoming worn and the chain jumping the sprocket teeth. It may also be caused by shafts out of parallel or sprockets out of line.

CORROSION

When a chain is subjected to corrosion in the field, its mechanical properties are impaired. There is usually a general roughening of the surface, such as pitting and the formation of rust (Fig. 39).

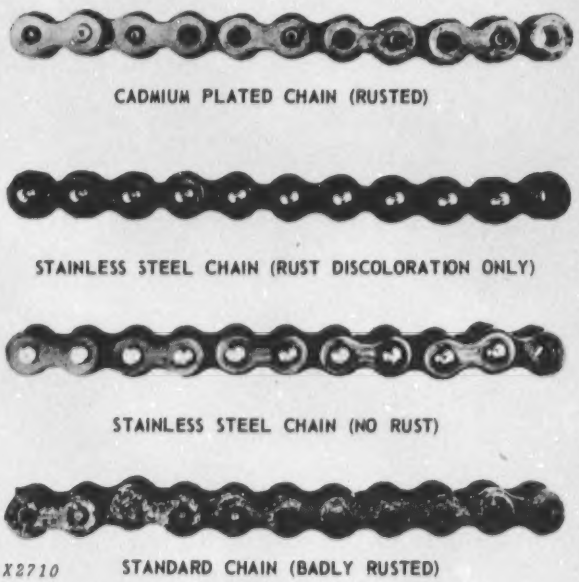
CADMIUM PLATED CHAIN (RUSTED)
STAINLESS STEEL CHAIN (RUST DISCOLORATION ONLY)
STAINLESS STEEL CHAIN (NO RUST)
X2710
STANDARD CHAIN (BADLY RUSTED)

Fig. 39 — Corrosion Of Chains (Atmospheric Corrosion)

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TIGHT JOINTS

X2711

Fig. 40 — Tight Joints In Chain Strand

Tight joints, or stiffness of roller chain links (Fig. 40), generally result from the roller link bars moving off the ends of the bushings and rubbing against the pin link bars. This occurs most frequently at very high operating loads, and is accelerated by lack of lubrication. Chains are designed to resist this type of chain failure, and if it develops, it can be alleviated only by improving lubrication of the drive or by using larger chain.

Tight joints can also be caused by material between the chain parts, or by peening over the edges of the link bars from interference with an oversize hub on the sprocket, or by other obstructions in the chain path.

If a chain has become stiff because of material build-up in the joints, the chain should be thoroughly cleaned and relubricated. If this proves inadequate, an extra clearance chain should be considered.

If the stiffness results from peening on the link bars, the drive should be checked for alignment and obstructions.

If there is evidence of misalignment, i.e., wear on the inside of the link bars of the roller link, check the shaft and sprocket alignment. Misalignment may also be a factor in tight joints.

SPROCKET WEAR

Sprockets manufactured with the proper tooth form are essential for smooth drive operation and optimum chain service life.

If replacement chains give less service than the originals, check the sprockets for excessive wear.

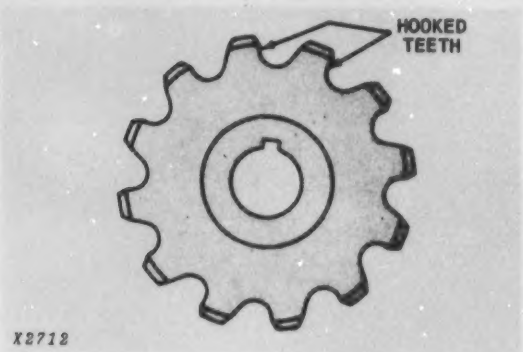

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Fig. 41 — Worn Sprockets

Sprockets should be replaced when tooth wear progresses to a point where the teeth have a **hooked** appearance (Fig. 41).

The amount of sprocket tooth hooking a drive can tolerate before serious chain damage occurs varies with drive conditions. Generally, as sprocket speed and chain loading increase, the allowable amount of tooth hooking decreases. On exposed drives, sprockets with hardened teeth should last as long as three strands of chain.

If not too badly worn, sprockets can be reversed to allow the chain to engage the unworn face of the tooth. However, in many cases, the hub projection interferes with bearings or frame members, preventing sprocket reversal. Also use caution in reversing sprockets on high-speed drives. Do not reverse when the back sides of the teeth show any signs of wear.

When new sprockets are installed, they should be carefully aligned on the shafts with a straight edge. Misalignment increases drive noise level and also increases chain and sprocket wear. Chains operating on misaligned sprockets have a tendency to develop tight joints because sprocket teeth force the inside plates outward on the bushings, thus binding the joint.

A worn sprocket in a misaligned drive will show abnormal wear on the **side** of its teeth.
To diagnose various kinds of sprocket failures, see the trouble shooting charts which follow.

TROUBLE SHOOTING OF CHAINS

Here is a handy guide for diagnosing problems with chain drives.

A. EXCESSIVE NOISE

Possible Causes

1. Misalignment of sprockets
2. Too little or too much slack
3. Lack of lubrication
4. Loose casings or bearings
5. Chain or sprocket worn out
6. Too large a chain pitch size
7. Too few teeth on sprockets or idler

What To Do

1. Check alignment and correct
2. Adjust centers for proper slack, or idler take-up
3. Lubricate properly . . . check lubricating mechanism to be sure oil is reaching working parts
4. Draw up all bolts, and brace casings if necessary
5. Replace chain and/or sprocket (some sprockets can be reversed)
6. Check chain drive recommendation chart
7. Use sprockets with more teeth

B. WEAR ON CHAIN SIDE BARS OR LINK PLATES AND SIDES OF SPROCKET TEETH

Possible Causes

1. Misalignment

What To Do

1. Remove chain and correct alignment of sprockets and shafts

C. CHAIN CLIMBS SPROCKETS

Possible Causes

1. Poor fitting of chains on sprockets
2. Chain worn out
3. Lack of chain wrap on sprocket
4. Excessive chain slack
5. Material build-up in sprocket tooth pockets

What To Do

1. Make sure sprocket bottom diameters are not oversize
2. Replace chain and sprockets (some sprockets can be reversed)
3. Revise drive arrangement to get more sprocket teeth in contact with chain, or use idler take-up to increase wrap
4. Adjust centers or take-up for proper slack
5. Remove material build-up . . . protect drive from contact with foreign material, or use sprockets with mud relief, pitch line clearance.

D. BROKEN PINS, BUSHINGS OR ROLLERS

Possible Causes

1. Chain speed too high for pitch and sprocket size
2. Heavy shock or sudden loads
3. Material buildup in sprocket tooth pockets
4. Lack of lubrication
5. Chain or sprocket corrosion
6. Wrong or badly worn sprockets

What To Do

1. Use shorter pitch chain or equivalent or greater strength and/or check number of sprocket teeth to be sure it is within recommended limits for speed involved. Select a sprocket with increased number of teeth, if necessary.
2. Reduce shock loads (easy starts assure longer life)
3. Remove material build-up . . . protect drive from contact with foreign material, or use sprockets with mud relief, pitch line clearance
4. Lubricate properly

5. Protect from corrosion

6. Check sprockets for wear and correct bottom diameter.

E. CHAIN CLINGS TO SPROCKETS

Possible Causes

1. Wrong chain or badly worn sprockets

2. Heavy or tacky lubricant

3. Material buildup on DRIVE sprocket tooth pockets

What To Do

1. Replace chain and sprockets (some sprockets can be reversed)

2. Clean and lubricate properly

3. Remove material buildup . . . protect drive from contact with foreign material, or use sprockets with mud relief, pitch line clearance.

F. CHAIN WHIPS

Possible Causes

1. Excessive chain slack

2. High pulsating loads

3. One or more stiff chain joints

4. Uneven chain wear

What To Do

1. Install chain take-up or idler, or adjust centers

2. Reduce load where possible or replace chain with one of suitable strength

3. Remove stiff links, or drive back on pins to provide proper clearance between side bars (also see items H-1 to H-6 below)

4. Replace chain

G. CHAIN SURGING (CONVEYOR CHAINS)

Possible Causes

1. Chain too tight or too loose

2. Chain tightener in wrong location

3. Mechanical interference

4. Sprockets too small

5. Chain track worn

6. Lack of lubrication

7. Frozen chain joints or rollers

8. Concentrated loading

What To Do

1. Adjust for proper slack

2. Relocate tightener

3. Inspect for interference with chain

4. Use larger sprockets. (Pulsations in chain are much less with larger sprockets.)

5. Replace chain track

6. Lubricate properly

7. Free or replace frozen parts

8. Even out loading of conveyor

H. CHAIN GETS STIFF

Possible Causes

1. Lack of lubrication — causes wear

2. Corrosion

3. Excessive overloads

4. Material buildup in chain joint

5. Peening of side plate edges

6. Misalignment

What To Do

1. Remove chain if dirty or corroded . . . clean and lubricate properly

2. Protect chain from corrosion

3. Reduce overloads

4. Protect chain with guard . . . clean and lubricate more often

5. Check for chain interference and correct

6. Check sprocket and shaft alignment

I. BROKEN SPROCKET TEETH

Possible Causes

1. Obstructions of foreign material in chain guards

2. Excessive shock loads, especially with small, cast-iron sprockets

3. Chain climbing sprocket teeth

What To Do

1. Check chain and sprocket clearances . . . remove foreign material

2. Reduce excessive shock loads, or use steel sprockets

3. (See items C-1 to C-5 above)

J. CHAIN FASTENERS FAIL

Possible Causes

1. Vibration

2. Obstructions striking cotter pins

3. Cotter pins not installed properly (should be properly spread and drawn back snugly against side bar)

What To Do

1. Reduce vibration

2. Eliminate obstruction, or tap ends back until cotter fits snugly against side bars, or use riveted chain

3. Correct faulty installation

K. CHAIN DRIVE RUNS TOO HOT

Possible Causes

1. Operating faster than recommended speed

2. Lack of lubrication

3. Chain operating too fast for bath lubrication

4. Chain immersed too deeply in oil (bath-lubricated drive)

5. Chain or shafts rubbing against an obstruction or seal dragging

What To Do

1. Check drive for recommended maximum speed for type of lubrication used

2. Increase volume of oil and/or cool oil in reservoir

3. Use oil stream system of lubrication

4. Adjust oil level to proper height

5. Remove obstruction against which chain rubs

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TEST YOURSELF

QUESTIONS

1. Match each of the statements below with either "belt drives" or "chain drives."
   a. Have less slippage.
   b. Stretch at a faster rate.
   c. Less damage by oil and grease.
   d. Generally more flexible.
   e. Can operate at higher temperatures.
   f. Require initial tension when installed.
2. Name the three basic jobs of chains.
3. What is **pitch** of roller chains?
4. On horizontal chain drives, should the tightener be on the bottom or the top?
5. True or false? "Standard roller chain can operate in either direction."
6. On detachable link chain, should the hook ends travel forward or to the rear?
7. A horizontal chain drive has four feet between its shaft centers. How much chain sag should it have?
8. By looking at the mating on the sprocket teeth, how can you tell if the roller **chain** is badly worn?
9. How do the profiles of sprocket teeth change as they wear?

(Answers on page 53).

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ANSWERS

1. Flat, round, and V-belts.

2. b. From the *sides* of the sheave groove.

3. False. The *top* of the V-belt stretches.

4. To keep the belt on the pulley.

5. The shaft for the driven pulley (½-inch [152.4 mm] diameter) will turn twice as fast.

6. True.

7. a. Lack of belt tension. b. Overload.

8. False. Dressings may damage V-belts. Proper tension and correct loads are the major ways to prevent slipping.

9. Remove *all* tension from the belts during storage.

ANSWERS

1. a — Chain drives; b — Belt drives; c — Chain drives; d — Belt drives; e — Chain drives; f — Belt drives.

2. Transmitting power, converting motion, and timing or synchronizing (see Fig. 3).

3. Chain pitch is the distance between the centers of the rollers (Fig. 8).

4. On the bottom (Fig. 12).

5. True (Fig. 16).

6. Forward (Fig. 16).

7. One inch (¼-inch per foot).

8. A badly worn chain will ride up out of the tooth pockets. This is because it has "stretched" (Fig. 33).

9. The teeth get a "hooked" appearance from wearing by the chain on their forward edges (Fig. 41).